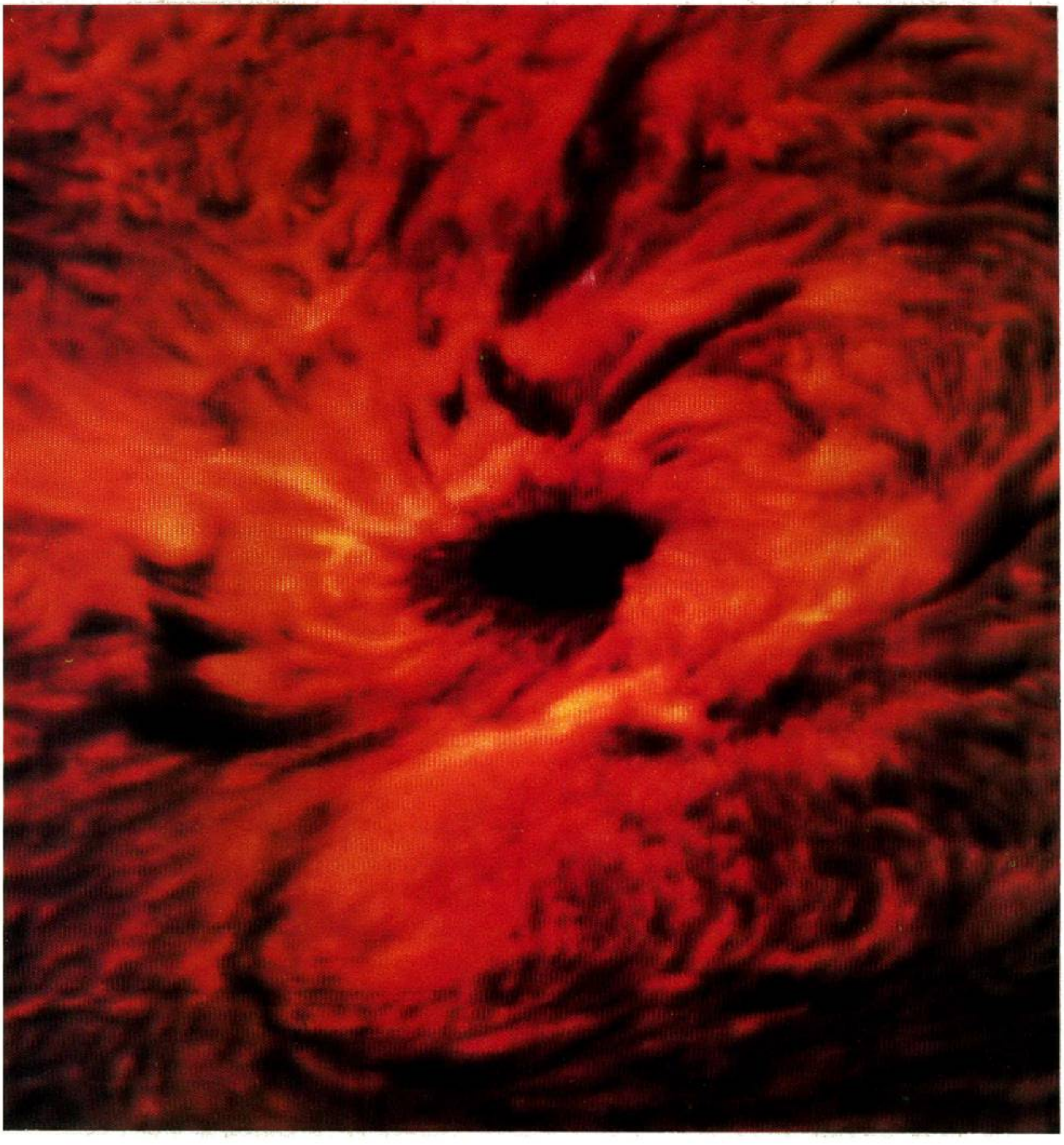
ASTRONOMY

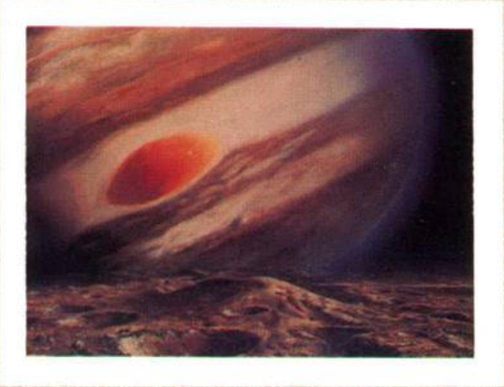
FEBRUARY 1978 $1.50



NEW FROM

To you, our readers, ASTRONOMY now offers a series of 8 dynamic, new, full color Art Reprints of some of the best paintings — by artists John Clark, Victor Costanzo, James Hervat, Mark Paternostro, Adolf Schaller and Rick Sternbach — that have appeared in ASTRONOMY Magazine.

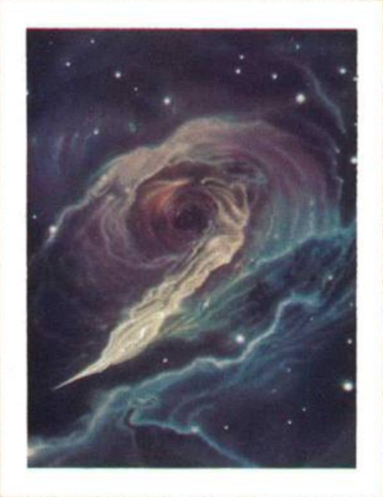
Adding to the drama, depth and realism of each piece, these Art Reprints are printed on 80 lb. linen finish paper, and are coated with a high gloss varnish. And each reprint is surrounded with a one inch white border,



Actual Size 17 x 22

Jupiter From Io

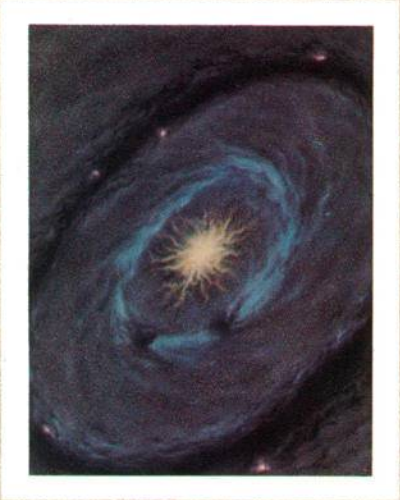
This dramatic painting reveals an incredible vista that man may never witness first hand: the incredible bulk of Jupiter looming over the surface of its satellite Io. Located deep within Jupiter's intense magnetic field, Io is one of the most lethal places in the entire solar system. To view this scene, we must rely on the imagination of artist John Clark.



Actual Size 17 x 22

Black Hole

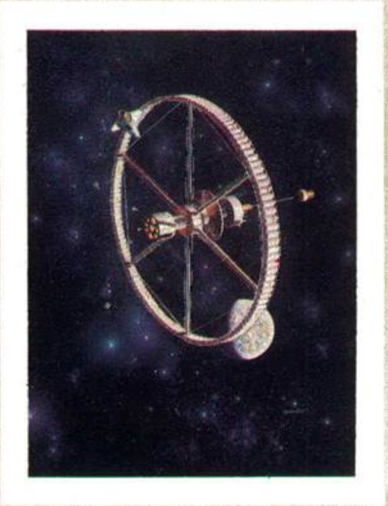
A nearly invisible small black hole speeds through a dense interstellar cloud of gas and dust, leaving behind a trail of gravitationally disturbed material. The infalling material becomes hot and emits light as it drains out of the known universe. Artist Mark Paternostro speculates on the appearance of these still undetected objects.



Actual Size 17 x 22

The Galactic Core

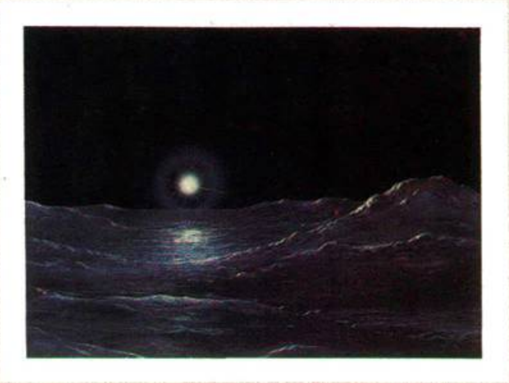
The nucleus of our galaxy is one of the true unknowns in our universe. Recent radio and infrared observations suggest that two titanic swirling rings of gas and dust occupy the core of our galaxy. These rings were apparently produced by an explosion 10 million years ago. Victor Costanzo's painting indicates that actual conditions at the galaxy's center remain a mystery.



Actual Size 17 x 22

Colony in Space

What will space stations and orbiting colonies of the future look like? Artist Rick Sternbach provides an ingenious answer in his painting of a mile wide space station wheeling slowly above the gibbous Earth. Shuttle rockets near the station's hub bring ore from the lunar surface for refinement in the station's zero gravity manufacturing center.



Actual Size 17 x 22

Pluto

The setting sun glints off a low plain of methane ice on the surface of the smallest and most distant planet, Pluto. The cold and forbidding scene — completely alien to Earth dwellers — comes to life in this rendition by James Hervat. The mysteries of Pluto are brought home to us as we stand and gaze back toward our incredibly distant sun.

ASTRONOMY

making it easier to frame, or suitable for hanging as is.

These magnificent, colorful Art Reprints are available for only $2.00 each, plus $1.00 per order for shipping and handling. Or if you prefer, by ordering a full set of 8 Art Reprints, you can take advantage of our special price of $12.75 for a set of 8 — that's a 20% savings!! — plus $1.00 per order for shipping and handling.

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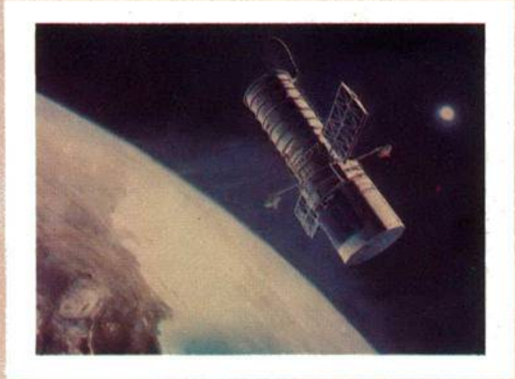

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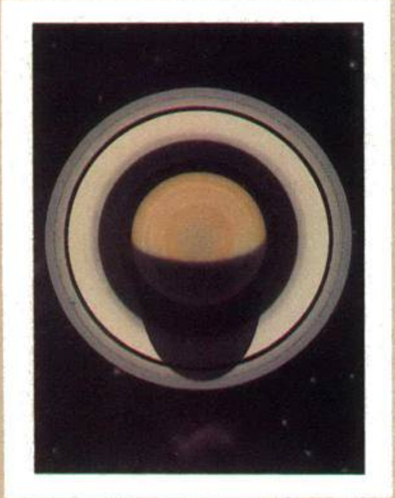
Space Telescope

Painted by John Clark from official NASA blueprints, this poster depicts the Space Telescope — a powerful 94 inch (2.4 meter) aperture telescope due to be launched during the early 1980s by NASA's Space Shuttle. This is an accurate depiction of an instrument that will revolutionize man's view of the universe during the decades it remains in operation.



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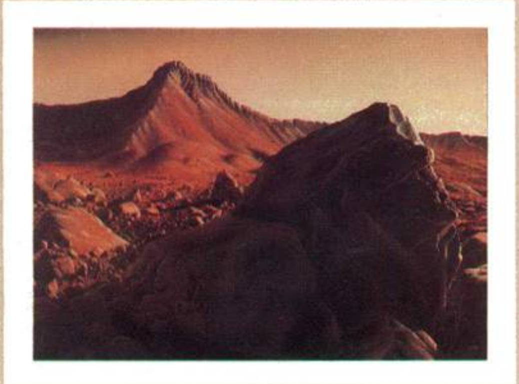
Saturn

In an unusual perspective from above the north pole of Saturn, we can identify the planet's three main rings and their sizes relative to Saturn itself, enabling us to grasp the vast extent of Saturn's ring system. This remarkable painting by Adolf Schaller gives us a view of the planet not obtainable from Earth.

Vallis Marineris

Photographs returned from Mariner and Viking probes revealed for the first time the immensity of Vallis Marineris, the equatorial canyon of Mars. This painting by Adolf Schaller — meticulously transcribed from overhead Viking photos — takes us to the foot of a blanket of landslide rubble in the canyon itself.



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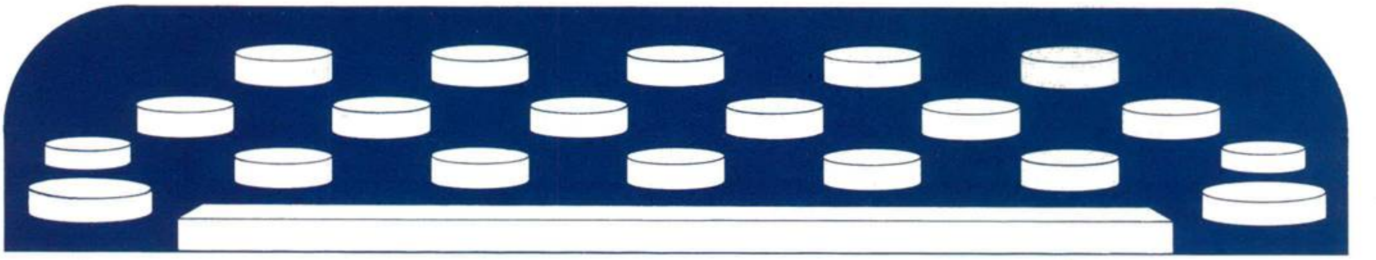

IN FOCUS

Sir / On clear nights in St. Louis, the smog and sky glow are not too bad for short exposure astrophotography — five minutes or less. But deep sky objects requiring long exposures are almost impossible to get with good results. The only solution that I've found is just to go out in the country somewhere.

M. MARSHA ALLEN
St. Louis, Mo.

Sir / I have lived in Brooklyn all my life, and have been an active observer for four years. The problem of light pollution severely limits what I can see and do, but it certainly does not stop me completely. I live in a three story apartment building that has a backyard where I am shielded from the glare of street lamps, and have a good degree of privacy. I also have the use of my roof, which gives me a view of the entire sky. My main interest is in the planets, for which clear dark skies are not a necessity. With a 2.4 inch refractor, I've made many observations of Mercury, Venus, Mars, Jupiter, Saturn, Uranus and Neptune, as well as some of the brighter asteroids.

All I really need is good seeing, which I very often have on clear nights. I have also observed some of the brightest deep sky objects on the very clearest nights — such as M-31, M-13, M-57, M-42, the Perseus double cluster, and a number of others. Once in a while we have very clear nights here, and I have recorded a number of them. On Aug. 6, 1972, and again on Aug. 6, 1973, from Staten Island (the most "rural" part of New York), you could see the brightest parts of the Milky Way in Cygnus, as well as M-31.

DAVID WIDMAN
Brooklyn, N.Y.

Sir / I do my observing from the backyard of my Buffalo, N.Y. home which is located about three miles from the center of the shopping and business district. Fortunately, very few businesses stay open past 5:30 p.m., so that the only illumination in that direction comes from mercury vapor streetlights. Unfortunately, they installed these lamps down side streets in my neighborhood several years ago, and a large battery of lights for night games at the park five blocks due west. When these park lights are on, the sky glow extends from the rooftops to some 45 or 50 degrees toward the zenith, depending on the amount of industrial pollutants there are in the air. This dust acts as a mirror to reflect back any surface illumination, which is the major reason why hooded lamps are preferred by city astronomers to at least prevent direct light spillage into the sky. My observing notes (I keep a notebook of objects seen) therefore contain such comments as very bright, bright or bright and hazy sky even though the transparency permits detection of fifth magnitude stars, or better with averted vision. The Milky Way is detectable about five times a year, so I suppose my Buffalo sky is better than some others. Also, I should mention that the proximity of Lake Ontario does produce air turbulence that adversely affects seeing.

Astrophotography is quite a bit more demanding. In ASTRONOMY, beautiful photos of deep sky objects are printed — photos taken from rural or dark sky locations. Little wonder that no pictures are submitted from city dwellers who (if they are like me) consider themselves blessed when constellation photos taken on Tri-X actually obtain images corresponding to most of the stars of that constellation on a sky fogged background, let alone Milky Way mosaics or the nebula surrounding Orion. Such people are discouraged when comparing their best efforts with those published. Perhaps, once in a while, a few city astrophotographs should be published — pictures of the bright stars of Orion or of M-33 as a barely visible smudge. It's my opinion that dark sky observers are less motivated than city observers! To continue observing under city skies, with all the associated problems, speaks of more dedication to astronomy. In my own case, I observe star clusters when only third magnitude stars are visible! How many dark sky observers would even consider taking the dust cover off their equipment when haze or clouds cut transparency to that limit?

So my advice to city dwellers is to keep observing, even with that 2.4 inch, and run down the list according to those polluted skies from deep sky objects through star clusters down to planets and the moon. You'll never regret the time spent. It teaches you your place in the scheme of things!

DAVID M. FLISS
Buffalo, N.Y.

Sir / My daughter and I have ground a four inch telescope mirror and are now ready to have it aluminized. Please tell us who provides this type of service.

CHARLES H. KITCHENS
Atlanta, Ga.

Mr. Kitchens / When sending your mirror to be aluminized, be sure to pack it securely in a box made of 1/4 to 1/2 inch thick plywood; then pack that box in a larger cardboard box with plenty of packing. Be sure that your name and address are written on everything you want returned.

Below are the names of three firms that offer aluminizing for homemade telescopes. Included are an east coast, midwestern, and west coast firm.

Pancro Mirrors, Inc.
6413 San Fernando Rd.
Glendale, Calif. 91201
(213) 247-2238

Coating Research Corporation of Illinois
1008 Lunt Ave.
Schaumburg, Ill. 60193
(312) 894-3820

Evaporated Metal Films Corp.
701 Spencer Rd.
Ithaca, N.Y. 14850
(607) 272-3320

Please write to these companies for price lists and delivery times.

Ooops!

November 1977, page 22 — the Very Large Array radio telescope is being built by the National Radio Astronomy Observatory, which is operated by Associated Universities, Inc., under contract with the National Science Foundation. The article confuses Associated Universities, Inc. with the Association of Universities for Research in Astronomy, Inc., a totally different organization which runs, among other things, Kitt Peak National Observatory in Tucson, Ariz.

November 1977, page 39 — the article "The Southern Sky" stated that the globular clusters NGC-104 and NGC-362 are located "in" the Small Magellanic Cloud. Actually, the two clusters are only located along the same line of sight as the SMC, and are much nearer than it. Also, the globular cluster listed in the table as NGC-6572 should be NGC-6752.

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Richard Berry

Associate Editor
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James Mullaney
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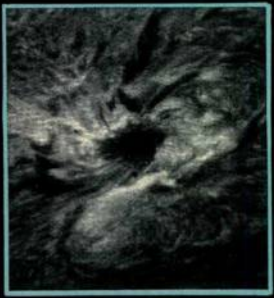

COVER

This month ASTRONOMY takes a look at the sun in a historical sense — tracing its activities back over many thousands of years — and examines the intimate bond between the sun's health and the welfare of the beings on the third planet. We'll also show you how you can photograph the moon and what you can see with a six inch telescope you could build yourself! Our cover photograph shows a sunspot centered in a churning region of solar activity. Kitt Peak National Observatory photograph, copyright © Association of Universities for Research in Astronomy, Inc.

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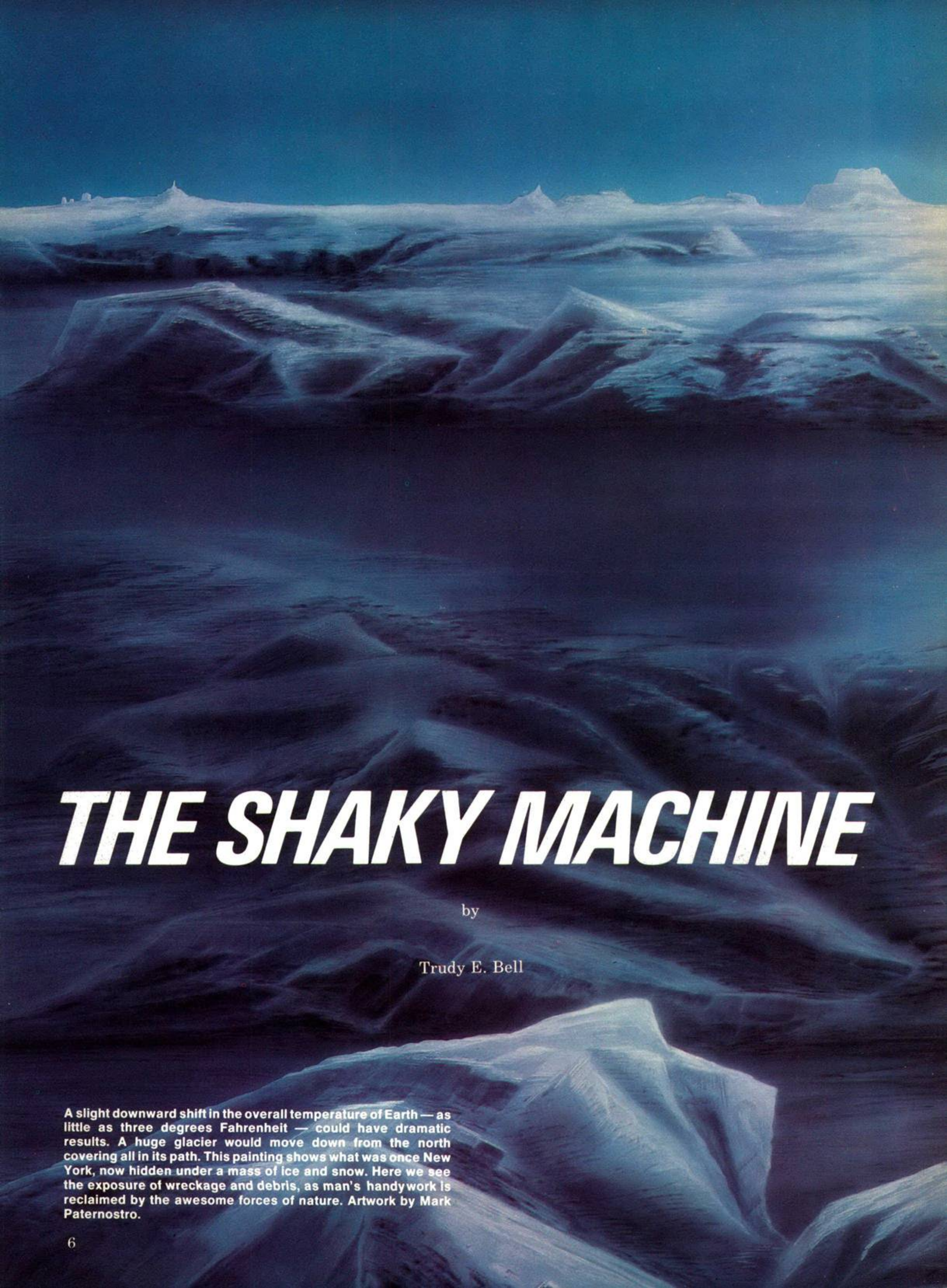
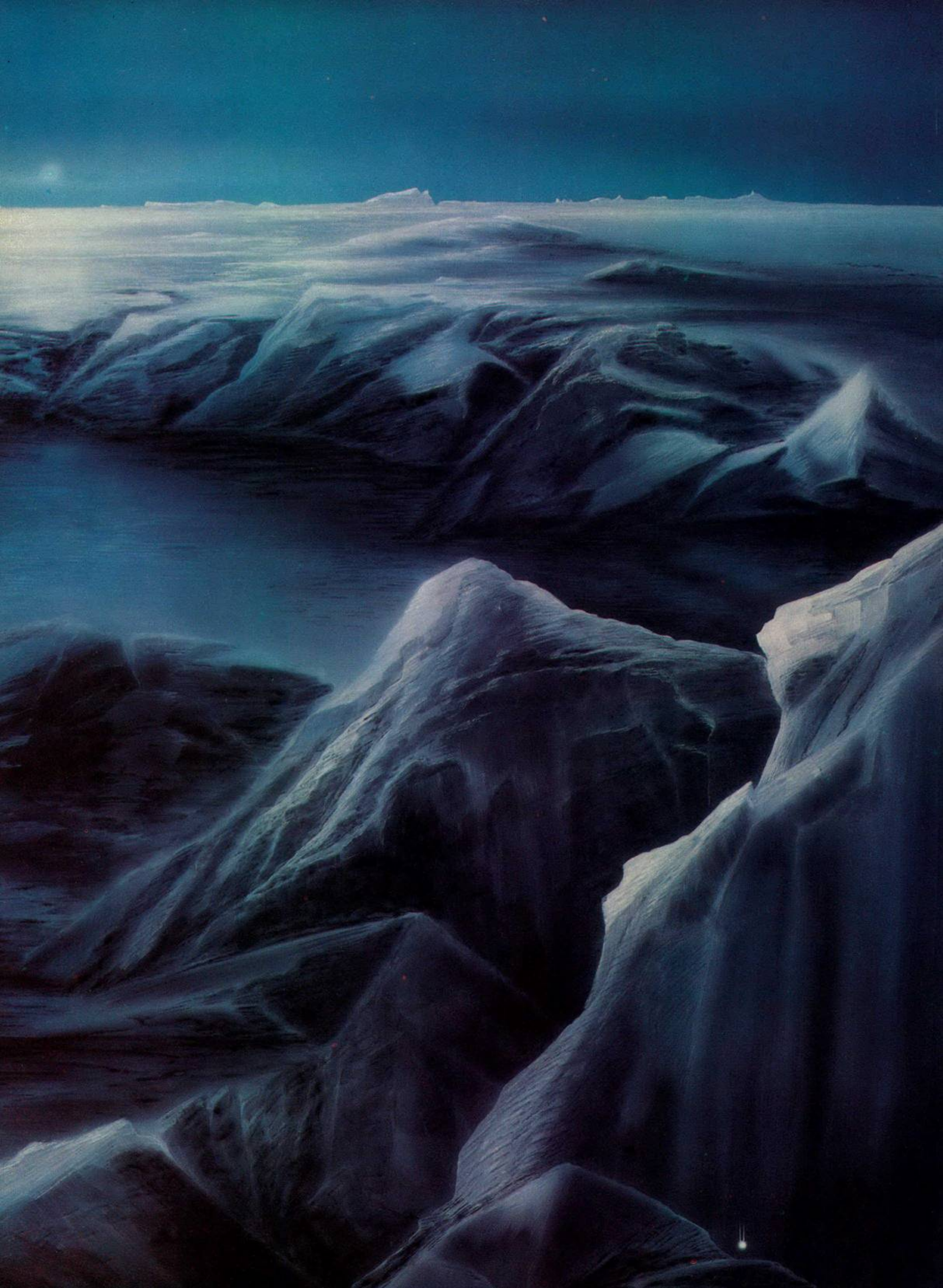


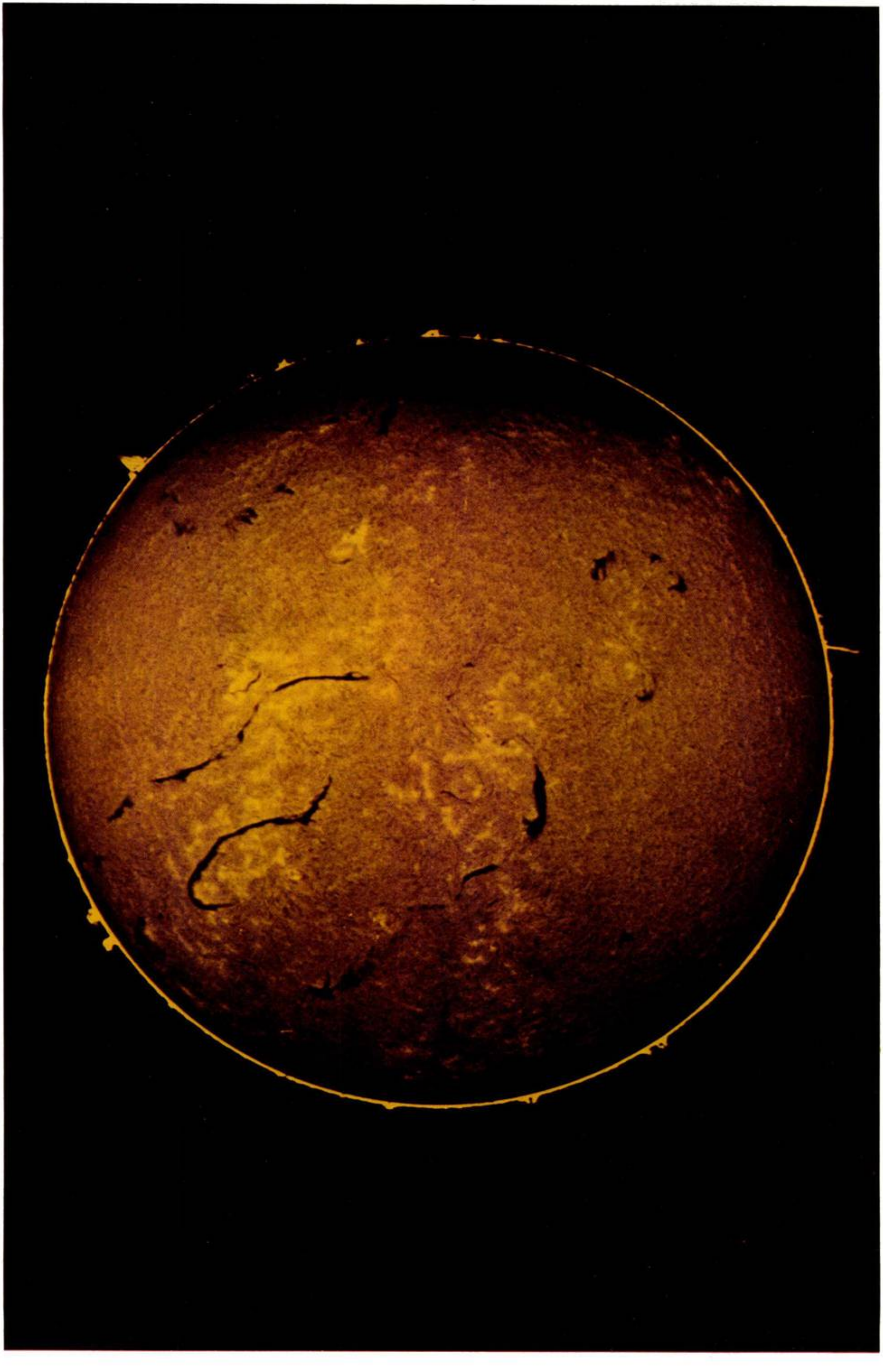
THE SHAKY MACHINE

by

Trudy E. Bell

A slight downward shift in the overall temperature of Earth — as little as three degrees Fahrenheit — could have dramatic results. A huge glacier would move down from the north covering all in its path. This painting shows what was once New York, now hidden under a mass of ice and snow. Here we see the exposure of wreckage and debris, as man's handywork is reclaimed by the awesome forces of nature. Artwork by Mark Paternostro.





The sun may be a typical "garden variety" star behaving in a normal fashion. On the other hand, maybe it isn't. Its behavior is not constant. Even worse, it's not regular. In fact, only within the past year or two have we begun to realize how truly complex and capricious our sun's behavior is — and the implications for life on Earth are profound.

The connection between the sun and Earth is intimate and vital; quite simply it is a matter of life and death. On a global scale the sun powers Earth's climate — energizing the winds in the atmosphere and ocean currents. If the sun stopped shining, the atmosphere would lose its supply of energy in two weeks, and the oceans in about 5,000 years. On a local scale, the sun's energy is absorbed by green plants through photosynthesis. The plants capture the energy in their chlorophyll and use it (in ways still not fully understood) to grow and mature, giving off the oxygen we breathe as a byproduct. Animals and people that eat plants for nourishment thus refuel on the plants' stored energy from the sun. Moreover, the energy in the oil and coal we use today came from the sun millions of years ago; this energy was trapped in plants that grew in steaming prehistoric swamps, that died and were slowly compressed into fossil fuel — liquid and frozen sunshine.

The solar connection is also finely balanced. If the average temperature on Earth *dropped* a mere three degrees Fahrenheit, a glacier would eventually move down from the north, engulfing Manhattan Island. If the average temperature *rose* by three degrees, the melting of the polar icecaps would raise the level of the ocean so that the Statue of Liberty would be submerged! Some climatologists believe there is evidence that we may now be entering another dustbowl period of drought and perhaps even famine in some parts of the world — and that such periods occur approximately every 22 years. Some investigators suspect that such dustbowl periods may be linked with a double sunspot cycle.

On an even grander scale, it appears that the presence or absence of sunspots heralds some kind of periodic deep-seated change within the sun's core which has truly dramatic effects on Earth's climate. For example, as recently as the reign of Louis XIV (1643 to 1715), there was a period lasting 75 years when there were virtually no sunspots on the sun, coinciding with the depths of the little ice age when remarkably severe winters numbed Europe and caused the Norse colony on Greenland to succumb.

Clearly we need to closely investigate the sun in order to fully understand the solar connection. Perhaps if we learn exactly what's happening up there, we might be able to predict what its effects will be on Earth — and if need be, prepare for them.

The sun is a scene of intense activity with many events taking place. Around the rim prominences reach outward, expending tremendous amounts of energy. The dark lines on the surface are also solar prominences; the longest line on the disk is approximately 35 Earth diameters or 227,000 miles (446,000km) long. The white patches mottling the sun's disk are flares. High Altitude Observatory photograph.

The sun is an inconceivably immense controlled thermonuclear reactor — a seething sphere of mostly hydrogen gas 864,000 miles across with the volume of a million Earths! In the core of the sun the temperature is so great — 27 million degrees Fahrenheit — that the nuclei of hydrogen atoms fuse together to form nuclei of helium atoms. Because four hydrogen nuclei, which are needed to make one helium nucleus, are actually somewhat more massive than the resulting helium nucleus, the extra mass is converted into energy according to Einstein's formula, $E = mc^2$. That energy is released in the form of high energy gamma rays that take 20 million years to leak to the sun's surface. In the process, they are transformed into radiation that spans the entire spectrum from the most energetic gamma rays and x-rays through ultraviolet radiation, visible light, infrared, microwaves, down to the longest radio waves.

Here on Earth we have created minature suns, both in controlled fusion reactors in our search for alternative energy sources, and in the hydrogen bomb. The reason that the sun itself does not explode like a hydrogen bomb is that it is so massive that its tremendous gravitational field holds it together.

Nonetheless, the surface of the sun is far from quiescent. Vast prominences leap from it, sometimes as far as 300,000 miles into space. Flares brighten small areas and then subside. Dark sunspots, looking much like whirling solar tornados, form and grow, eventually breaking apart. Hovering above the surface is the ghostly solar corona, with a temperature of more than one million degrees. From it the sun throws out a varying flux of subatomic particles and magnetic fields that expands through the entire solar system as the tenuous solar wind.

Sunspots were first discovered in the Western world around 1610, when Galileo and several of his contemporaries first focused their newly invented telescopes on the most obvious heavenly body. They could see that the spots were not permanent features: They crossed from one side to another over a period of about two weeks. Galileo and others correctly attributed that motion to the fact that the sun was rotating, with a period of about 25 days. Furthermore, there sometimes were no spots at all on the face of the sun; at other times there were so many in a group or the individual spots were so large that they could even be seen with the unaided eye.

In the 19th century, Heinrich Schwabe, a German amateur astronomer, discovered that the number of spots on the sun seemed to vary periodically, reaching a maximum in a cycle of perhaps 10 to 11 years. Several 19th century investigators sought to trace that cyclical record back as far as they could. Although the principal historical investigator, German astronomer Max Wolf, culled old literature and observatory archives back to the first telescopic observations in 1610, the mean annual sunspot numbers he chose to publish cut off at 1700. His record of sunspot observations, combined with modern observations, cover a period of more than 250 years. The quality of the record is not even throughout; after 1848 it is highly reliable, but before 1748 it is poor. Nevertheless, the record does show the cyclical variation of the number of sunspots each year.

But if we take a closer look, we'll quickly see that the sunspot cycle is not really very regular at all. It's immediately evident that some sunspot maxima were far greater than others. Some seem to have two peaks of maximum activity separated by about a year. Some of the cycles seem to have maxima separated by as little as seven or eight years, whereas other cycles have their maxima as far apart as 15 years or even more. In fact, no two sunspot cycles seem at all alike.

What about the sunspot cycle before 1700? In the 17th century there were quite a few superb astronomers with perfectly adequate telescopes: Christopher Scheiner, John Flamsteed, Christian Huyghens, Edmund Halley, Jean Dominique Cassini. Where is their data? Did those observers ignore the sun for the first 90 years of telescopic astronomy? Did Wolf feel that using data from the 17th century was stretching historical credibility too far, or was it something else?

Piqued by these or similar questions, in the late 19th century a German solar astronomer, Gustav Spörer, started re-examining the very early historical records for sunspot data. In 1887 and again in 1889, shortly before his death, Spörer published the astounding results of his detective work: It seemed that for a period of about 70 years (ending around 1715), the sun was almost totally devoid of sunspots.

At that point British astronomer E. Walter Maunder at the Royal Greenwich Observatory began some sleuthing. In 1894 he published a detailed account of Spörer's work in a paper called "A Prolonged Sunspot Minimum". Maunder pointed out that to admit that such an unusual phenomenon had occurred was to admit that the sunspot cycle — and indeed, the sun itself — had somehow changed during recent history, and that it could possibly do so again. He stressed the implications not only for our understanding of the sun, but also for our understanding of the relationship between the sun and Earth.

In spite of the spectacular nature of Maunder's conclusions, solar physicists apparently ignored them. Three decades later, Maunder republished the same results along with new information — and that paper also seems to have been resoundingly ignored. Maunder died in 1928, and interest in the subject seemed to have died with him.

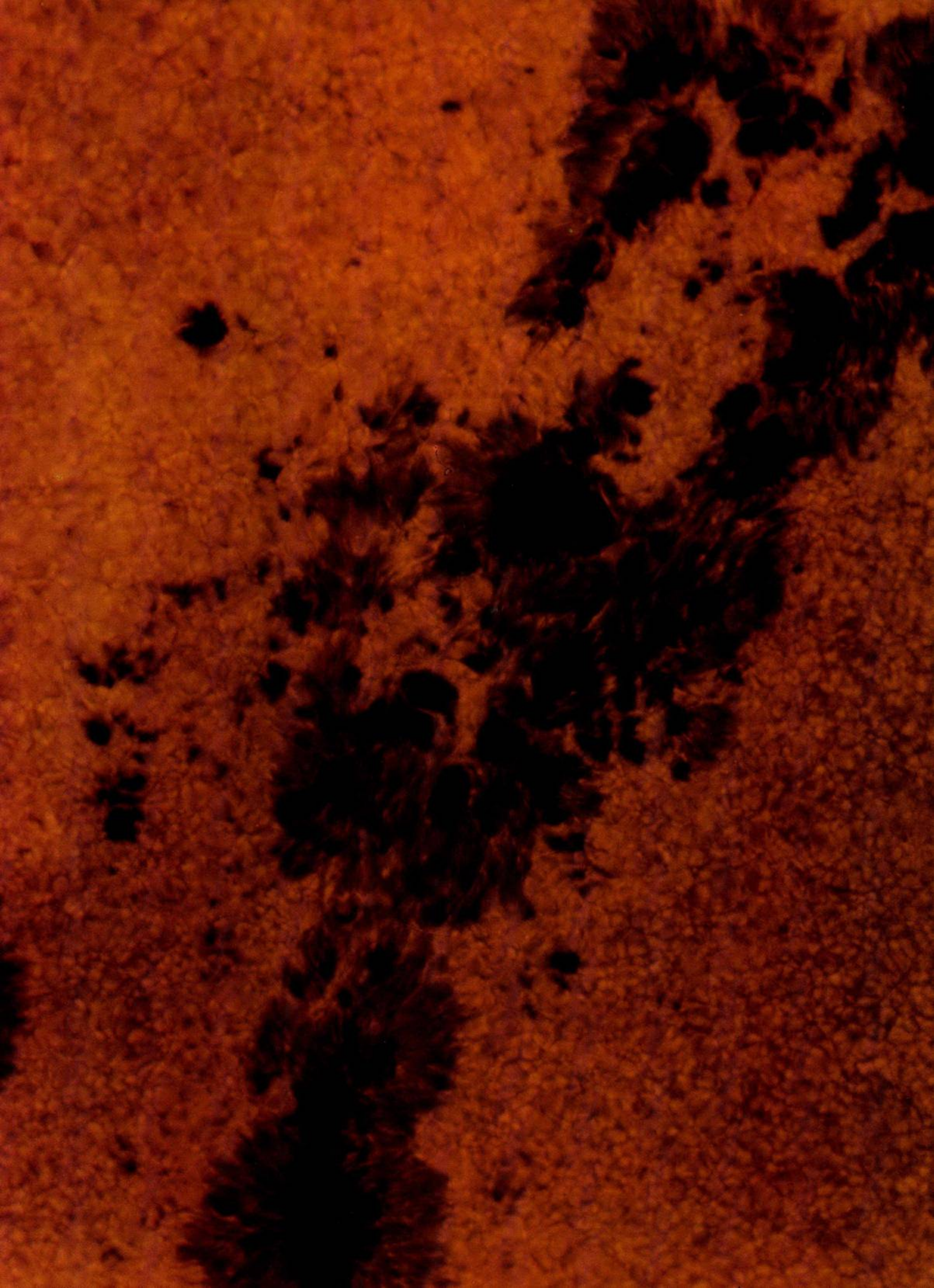
The curious problem rested for nearly a half century. Then several years ago John A. Eddy, a solar physicist at the High Altitude Observatory in Boulder, Colo., decided it was time to clear up the case of the missing sunspots. "It had hung too long like a skeleton in the closet of solar physics. I was annoyed by occasional references to it in association with a coincident change in world climate. As a solar astronomer I felt certain that it could never have happened, and my interests in history made the task of correcting Maunder's mistake an appealing one. It had the ring of a detective story: A crime, serious to astronomy and perhaps to Earth itself, had been reported committed long in the past. Did it really happen?"

Maunder's original clues, more than 250 years old, were still readily available in libraries in 17th and 18th century journals. Eddy found from these sources that not only was there indeed a dearth of spots on the sun, but that such an absence was widely discussed by 17th century astronomers and was even then acknowledged as strange. *No* sunspots were seen during the 1660s, and when one was finally reported in 1671, the last sunspot seen — 11 years earlier — was briefly described for those who had forgotten what one looked like. Furthermore, from other astronomical observations astronomers were making at the time, it was clear that observers of the 17th century were capable and systematic, and had had telescopes adequate to detect any visible spots on the sun — had there been any.

Historical records further revealed that auroral displays — the flickering red and green northern and southern lights — were almost totally absent. Aurorae are strongly correlated with the activity of the sun. The displays are created when charged particles from the sun encounter Earth's magnetic field, which accelerates the particles and guides them into our atmosphere; there they collide with air molecules which causes them to glow. The sun emits more particles from active regions, such as flares or sunspots, than it does from inactive regions. Aurorae are particularly valuable as a historical indicator because they are spectacular, easily seen, require no telescopic apparatus, and are visible over wide geographical areas. They were also frequently interpreted as religious or astrological omens, so their appearance usually caused considerable excitement.

Searching for more evidence, Eddy combed historical records of observations of total eclipses of the sun. Anyone who has ever witnessed a total

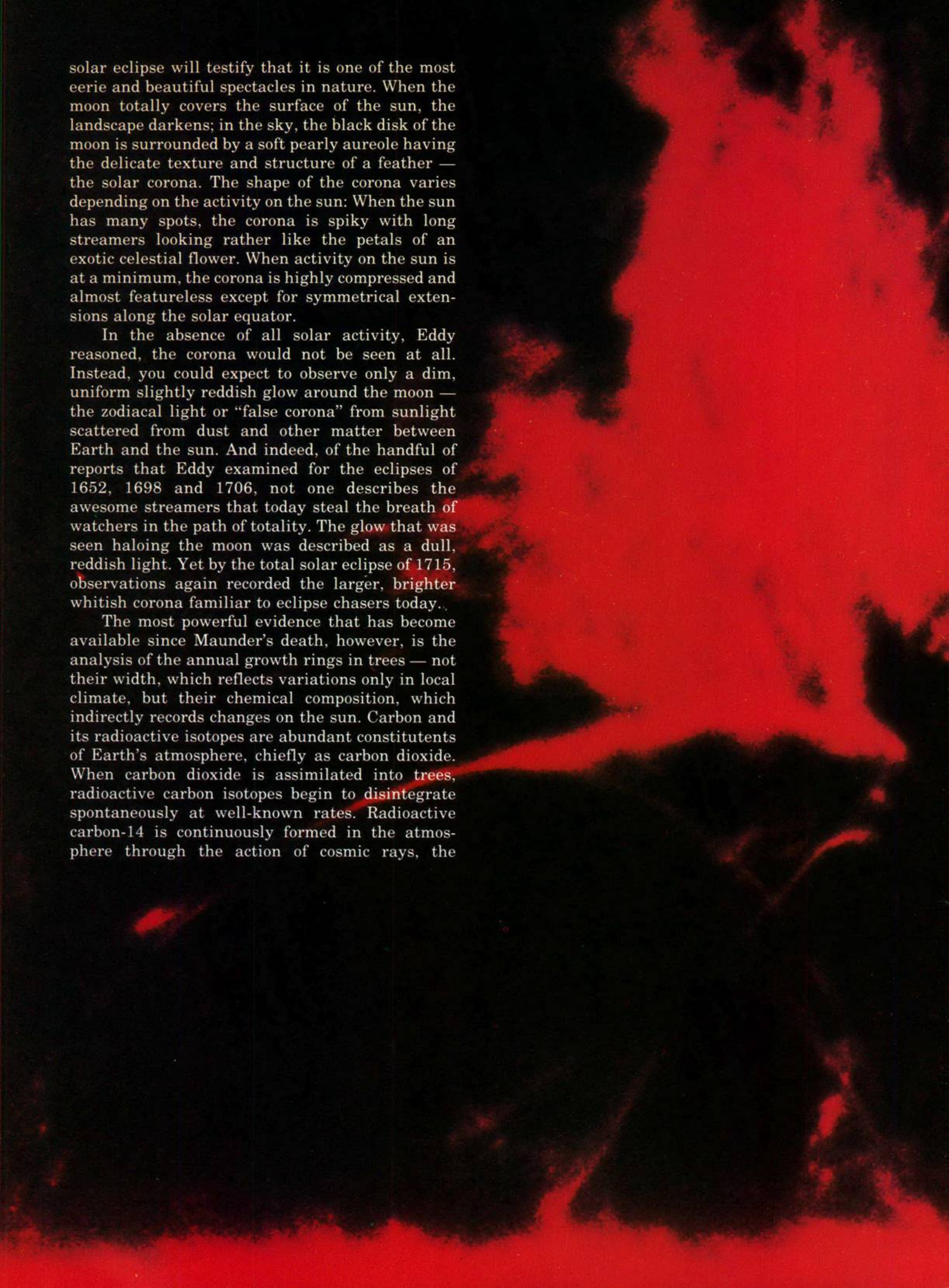
This photograph shows a complex chain of sunspots and the assorted granulated shapes surrounding them. Sunspots, which are actually very hot, appear dark only in contrast to the brighter surrounding photosphere. Sacramento Peak Observatory photograph.



solar eclipse will testify that it is one of the most eerie and beautiful spectacles in nature. When the moon totally covers the surface of the sun, the landscape darkens; in the sky, the black disk of the moon is surrounded by a soft pearly aureole having the delicate texture and structure of a feather — the solar corona. The shape of the corona varies depending on the activity on the sun: When the sun has many spots, the corona is spiky with long streamers looking rather like the petals of an exotic celestial flower. When activity on the sun is at a minimum, the corona is highly compressed and almost featureless except for symmetrical extensions along the solar equator.

In the absence of all solar activity, Eddy reasoned, the corona would not be seen at all. Instead, you could expect to observe only a dim, uniform slightly reddish glow around the moon — the zodiacal light or "false corona" from sunlight scattered from dust and other matter between Earth and the sun. And indeed, of the handful of reports that Eddy examined for the eclipses of 1652, 1698 and 1706, not one describes the awesome streamers that today steal the breath of watchers in the path of totality. The glow that was seen haloing the moon was described as a dull, reddish light. Yet by the total solar eclipse of 1715, observations again recorded the larger, brighter whitish corona familiar to eclipse chasers today.

The most powerful evidence that has become available since Maunder's death, however, is the analysis of the annual growth rings in trees — not their width, which reflects variations only in local climate, but their chemical composition, which indirectly records changes on the sun. Carbon and its radioactive isotopes are abundant constitutents of Earth's atmosphere, chiefly as carbon dioxide. When carbon dioxide is assimilated into trees, radioactive carbon isotopes begin to disintegrate spontaneously at well-known rates. Radioactive carbon-14 is continuously formed in the atmosphere through the action of cosmic rays, the

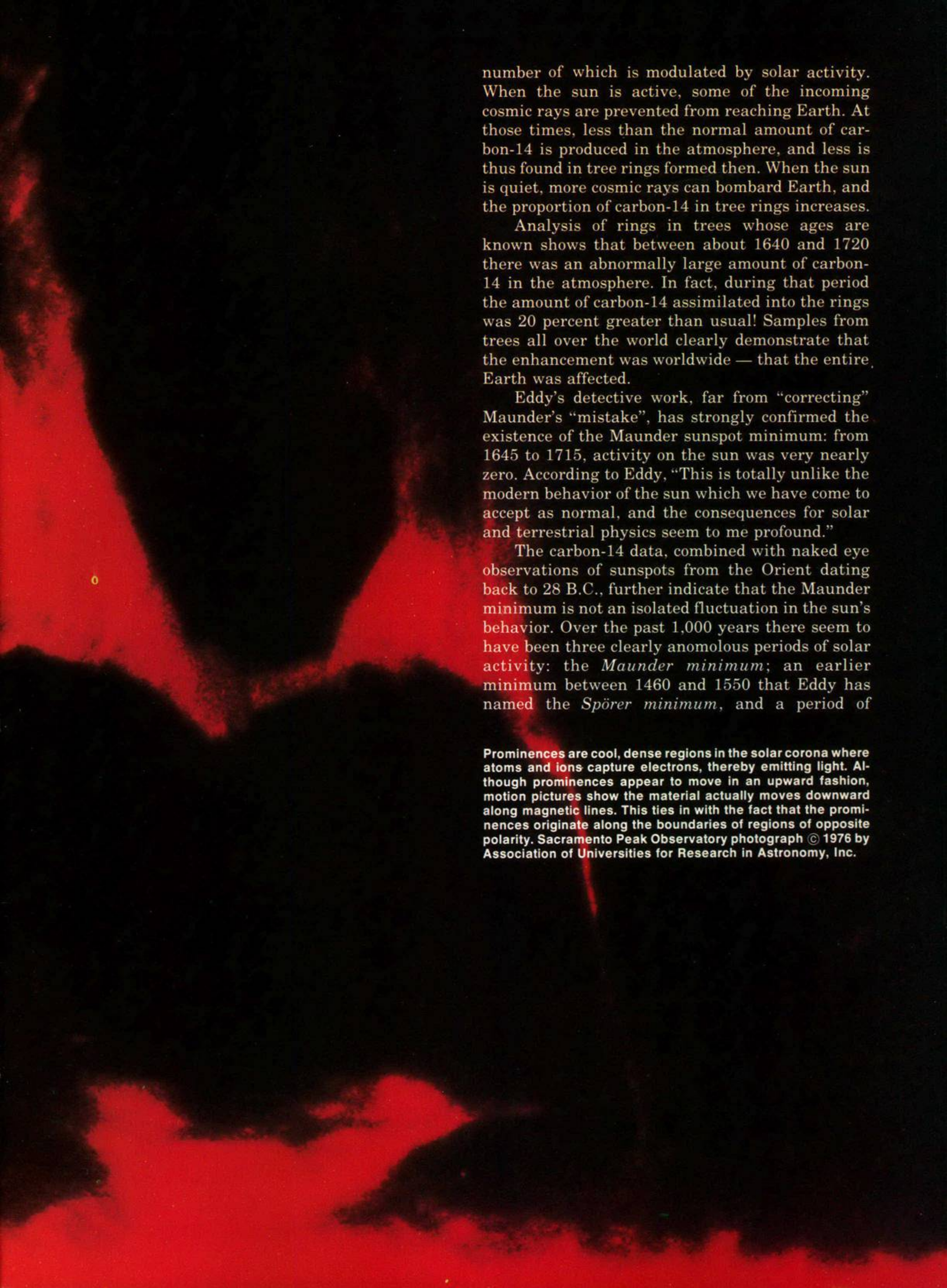


number of which is modulated by solar activity. When the sun is active, some of the incoming cosmic rays are prevented from reaching Earth. At those times, less than the normal amount of carbon-14 is produced in the atmosphere, and less is thus found in tree rings formed then. When the sun is quiet, more cosmic rays can bombard Earth, and the proportion of carbon-14 in tree rings increases.

Analysis of rings in trees whose ages are known shows that between about 1640 and 1720 there was an abnormally large amount of carbon-14 in the atmosphere. In fact, during that period the amount of carbon-14 assimilated into the rings was 20 percent greater than usual! Samples from trees all over the world clearly demonstrate that the enhancement was worldwide — that the entire Earth was affected.

Eddy's detective work, far from "correcting" Maunder's "mistake", has strongly confirmed the existence of the Maunder sunspot minimum: from 1645 to 1715, activity on the sun was very nearly zero. According to Eddy, "This is totally unlike the modern behavior of the sun which we have come to accept as normal, and the consequences for solar and terrestrial physics seem to me profound."

The carbon-14 data, combined with naked eye observations of sunspots from the Orient dating back to 28 B.C., further indicate that the Maunder minimum is not an isolated fluctuation in the sun's behavior. Over the past 1,000 years there seem to have been three clearly anomolous periods of solar activity: the *Maunder minimum*; an earlier minimum between 1460 and 1550 that Eddy has named the *Spörer minimum*, and a period of



Prominences are cool, dense regions in the solar corona where atoms and ions capture electrons, thereby emitting light. Although prominences appear to move in an upward fashion, motion pictures show the material actually moves downward along magnetic lines. This ties in with the fact that the prominences originate along the boundaries of regions of opposite polarity. Sacramento Peak Observatory photograph © 1976 by Association of Universities for Research in Astronomy, Inc.

unusually great activity from 1100 to 1250, which Eddy termed the *Grand maximum*.

Likening the sunspot cycle to an electrocardiogram, Eddy said, "I don't think that such irregularity is a mark of health. I think it's the mark of a shaky, rickety machine."

What could be happening deep inside the sun to bring such erratic behavior?

In the mid-1960s, some years before Eddy became involved in the case of the missing sunspots, Raymond Davis Jr. of the Brookhaven National Laboratory independently began investigating the thermonuclear processes deep in the solar interior to confirm the calculations of solar theory.

We can't peer into the sun's core simply by looking at photons of light shining from the sun's surface. The interior of the sun is so dense that the radiation we are receiving today was produced in the sun's core several million years ago. The subatomic particles in the core are so compacted, however, that each photon released by the fusion of hydrogen into helium travels only a short distance before it is absorbed by a neighboring particle. Eventually that particle emits a photon, which travels only a short distance farther before it is absorbed by yet another particle. Only in such a torturous way do photons slowly, laboriously zigzag their way some 400,000 miles from the core to the surface of the sun, where they finally escape at the speed of light and reach Earth 8 minutes 20 seconds later.

Because of the tedious way photons travel from the core of the sun to the surface, the "news" they bring with them about the solar interior is millions of years stale — and much transformed. Davis' idea for peering into the sun's core involved detecting something different. There is one remarkable particle that is also a byproduct of the thermonuclear reactions in the sun's core — the neutrino. Like the photon, the neutrino has no mass and no charge, and it travels at the speed of light. Unlike the photon, however, the neutrino interacts with almost nothing; a neutrino could speed through light-years of solid lead and not be absorbed. Thus any solar neutrinos from deep within the sun's core arriving at Earth would carry news about the sun's interior that was not millions of years old, but only about 8 minutes 23 seconds old — barely more than the length of time it takes neutrinos to cross space from the surface of the sun to Earth.

The problem facing Davis in trapping these neutrinos was monumental. Because neutrinos are such effective probes of the solar interior, they are also extraordinarily difficult to detect: How do you capture something that can penetrate untold miles of solid lead?

A neutrino of the proper energy will occasionally interact with an atom of chlorine-37, transmuting it into an atom of the radioactive isotope argon-37. Chlorine-37 is not difficult to obtain — in fact, it's a major constituent of the common dry cleaning solvent perchloroethylene. Get enough chlorine-37 together in one place, Davis reasoned, and it should be possible to begin to detect neutrinos from the sun.

Between 1964 and 1967, Brookhaven National Laboratory constructed a large-scale neutrino detector: simply a huge tank holding 100,000 gallons of dry cleaning solvent! Because cosmic rays and other particles bombarding the surface of Earth can also transmute chlorine-37 into argon-37, the tank was buried one mile under solid rock in the Homestake Gold Mine in Lead, S.D. — thus shielding the liquid from everything but the energetic solar neutrinos. To further reduce reactions from background radiation in the rocks, the cavern holding the tank was flooded with water.

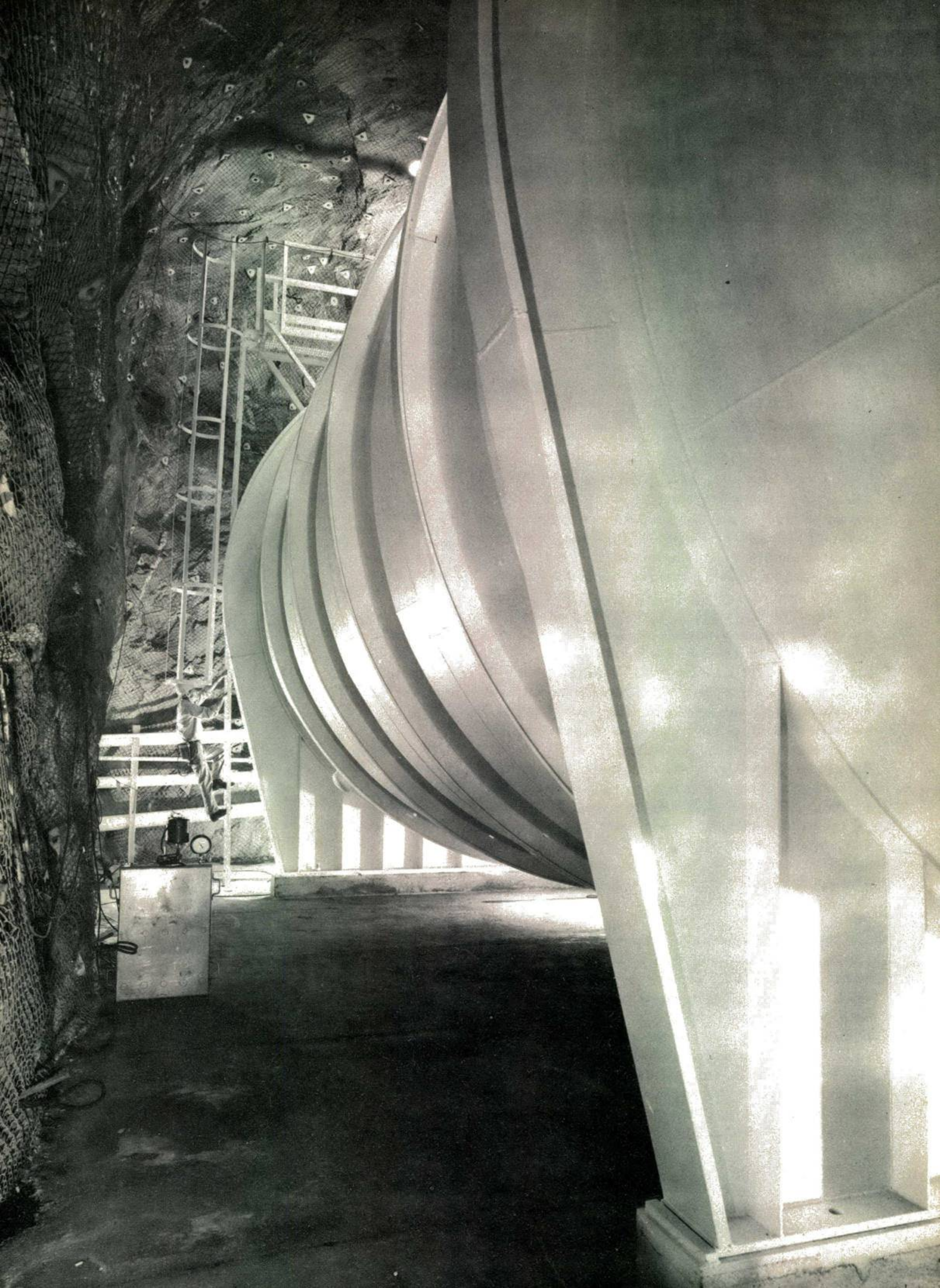
Most of the time the detector lay undisturbed, registering neutrinos from the sun. Once every few months or so the experimenters bubbled helium gas through the solvent in order to collect the argon-37 (its amount was measured by detecting its radioactive decay). The results of the experiment were expressed, with a touch of whimsy, in terms of solar neutrino units (SNU). Current theories of the solar interior indicated that the flux of neutrinos from the sun should be around 5.8 SNU. In terms of the Brookhaven detector, that meant that one atom of argon-37 should be created in the tank each day — thus demanding that the method of argon collection be so precise that it could find individual atoms in the volume of an Olympic swimming pool.

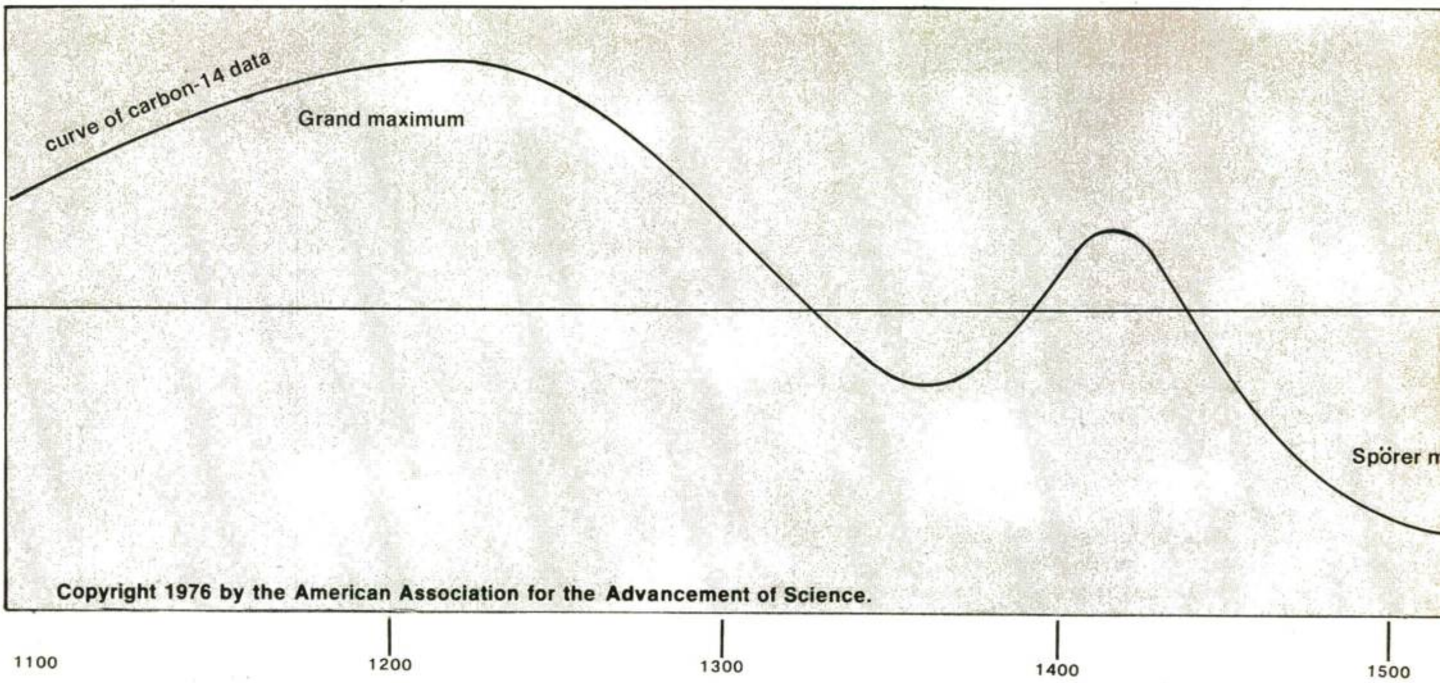
In 1968 the first results from Davis's experiment were available. To everyone's surprise, the amount of argon collected from the tank was four to eight times lower than expected. Davis improved the sensitivity of the tank and continued with the experiment. By late 1973 it was clear that something was direly wrong. The tank was registering only one neutrino induced event per *month* — 1/30 the number predicted, corresponding to a flux of solar neutrinos of approximately 0.28 SNU.

Solar physicists were seriously concerned. It seemed there could be only three possible explanations for such a large discrepancy: 1) something was wrong with the experiment; 2) something was wrong with our understanding of subatomic physics and the behavior of neutrinos; 3) something not understood is happening (or not happening) inside the sun.

Several solar physicists began devising new

This is the tank being used by Raymond Davis in his search for neutrinos — subatomic particles that have no mass, no charge and rarely interact with other matter. But a neutrino with the right amount of energy occasionally interacts with an atom of chlorine-37. Brookhaven National Laboratories built this tank and filled it with 100,000 gallons of dry cleaning fluid (of which chlorine-37 is a major constituent) in an effort to detect the neutrinos. The tank was built in the Homestake Gold Mine in South Dakota, one mile under solid rock in an effort to avoid other particles that may affect the chlorine-37. Brookhaven National Laboratories photograph.





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This diagram is an indication of solar activity since 1100 A.D. The curve running from 1100 to 1900 is a measure of the carbon-14 level in tree rings. When the sun is active, less than the normal level of galactic cosmic rays reaches Earth; consequently, less than the normal amount of carbon-14 is formed in the tree rings. The portions of the curve above the straight line indicate approximately 20 percent less than the normal amount of radiation. It follows that the parts below the straight line indicate 20 percent more than the normal level. From 1700 on, the diagram shows the average annual sunspot number which fluctuates up and down approximately every 11 years. This diagram is based on figures published by John Eddy in *Science*, Vol. 192, pg. 1189, June 18, 1976 and figures published by Stephen Schneider and Clifford Mass in *Science*, Vol. 190, pg. 742, Nov. 21, 1975.

theoretical models of the sun — some of them quite exotic — that would predict only a few neutrinos. Without radically changing the basic assumptions, it was possible to adjust conditions so that the predicted flux of solar neutrinos was 1.5 SNU — but still there was a disturbing discrepancy.

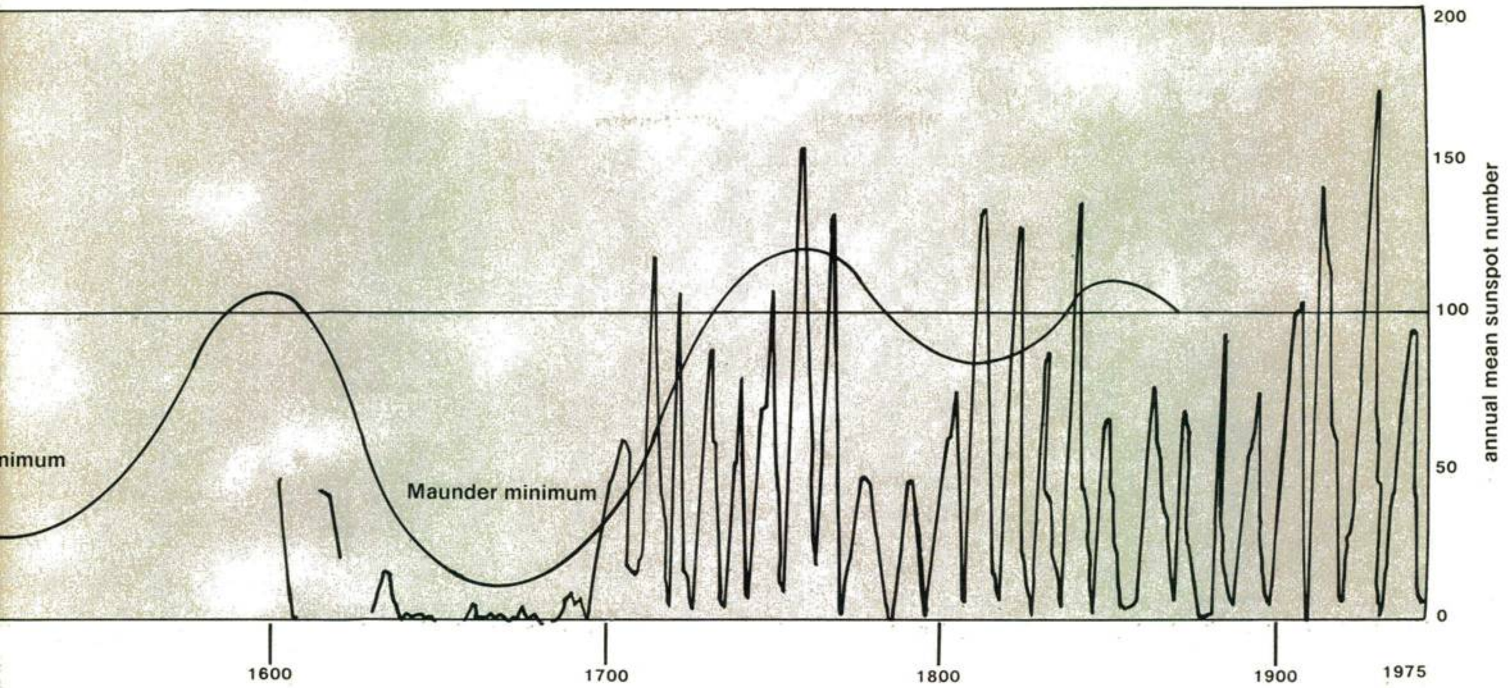
As if all this were not perplexing enough, in early 1975 the Brookhaven detector suddenly turned up a handful of neutrinos — four SNU. Davis had seen one previous high run of 5.5 SNU in 1972, however, so remained unimpressed. But then the next run was also high. And the next. This was truly bewildering, for there had been no change made in the sensitivity of the detector, in the background level of cosmic rays, in the natural radiation from the surrounding rocks, or in the way in which the sample had been removed. To the best of Davis' knowledge, the detector had not been contaminated. The only break in routine was that before the high runs, the water was temporarily drained from the cavern so that the tank could be inspected for corrosion and given a new coat of paint.

Could the sun have suddenly "turned on"? Davis was reluctant to think so. The recent high runs were within the bounds of statistical fluctuations. So until he feels there is reason to be convinced otherwise, he has averaged in the high runs with the previous low ones to obtain a flux of solar neutrinos of approximately 1.2 SNU.

Is the sun a shaky machine? Is it simply behaving like any other medium sized, middle aged star? As yet the answer remains: We don't know. There is only one way to find out — by keeping a close watch on it.

Over the past several years it has been discovered that the sun is oscillating — that is, portions of its surface are rising and falling between 700 and 1,400 miles in a period of about five minutes, rather like choppy ocean waves. At the same time, the entire body of the sun is vibrating as a whole, with acoustic waves traveling through it with a period of an hour or two — ringing, as it were, like a bell. Observations of other stars seem to indicate that other suns may be flickering very, very slightly on the timescale of an hour or two. Could that flickering be similar to the oscillations of our own sun? Could the nature of the oscillations tell us about the sun's structure rather like the nature of waves from earthquakes tell us about the interior of Earth? Could knowledge about the structure of the sun yield some more direct information about the nuclear processes generating energy deep inside the sun's core?

The problems are exciting, perplexing and vital — and they hit close to home. For example, the winter of 1976-77 was distinguished by record breaking low temperatures all across the country. At the same time the sun seems to be in another anomolous solar cycle — a prolonged minimum of solar activity that should have ended more than two years ago if the sun were on a regular 11 year sunspot cycle. Moreover, Robert Howard of the Hale Observatories reported that since 1967, the sun's equatorial rotation speed seems to have



increased by about five percent. Furthermore, historical study by Eddy and two colleagues has shown that during the early 1640s — just before the Maunder minimum — the equatorial rotation speed of the sun was three or four percent faster than present rates.

Are all these changes coincidental? Or are they deeply significant?

It is too early to tell. Variations in climate are certainly natural: Half the time winters will be warmer than average, and half the time they will be colder. An abnormally cold winter may be nothing more than a statistical fluctuation.

On the other extreme, it may be possible that we are entering another prolonged sunspot minimum like the Maunder minimum and the Spörer minimum. If so, there will be many more bitterly cold winters to come.

More people are beginning to seriously reexamine the sun-climate connection, and to publish the results of their findings — or at least to publish their questions. In late 1976, the National Research Council of the National Academy of Sciences published a lengthy report called **Climate and Food: Climatic Fluctuation and U.S. Agricultural Production**, recommending that further research be undertaken to understand climate and its variations, and their effects on food production. The report was preceded by a half year by Stephen H. Schneider's **The Genesis Strategy: Climate and Global Survival**, which urges countries to store up food supplies during fat years to tide them over during lean ones. The Central Intelligence Agency has published an internal working paper concluding that apparent changes in climate will result in new political alignments between nations to ensure a secure supply of food. According to the report, the politics of food could become the central issue for every government.

The climate may very well be responding to long-term variations in the output of the sun. Thus it is of paramount importance to solar astronomers, climatologists and the rest of us who eat, to precisely measure the output of the sun — the so-called solar "constant" — over a long period of time, in the hope that we might eventually be able to project a bit and see if the years ahead might be fat or lean. This would call for measuring the sun's output to an accuracy of 0.1 percent, to determine whether the solar constant is truly constant.

Our knowledge of that one pivotal piece of information is currently far too imprecise for adequate climatic theory. In the past, only one astronomer has attempted to measure it over any substantial period of time — Charles Greeley Abbot, who quietly devoted about 50 years to the project (less with the support of his colleagues, than in spite of them). Even so, Abbot's measurements are not sufficient; the instruments he used in the early 20th century were not as good as the ones available today, and all his measurements were made beneath the variable blanket of Earth's atmosphere. Today we have the potential to measure the sun's output much more precisely from outposts in space. The measurement is difficult, requires a long commitment of decades, and in itself it has no glamour or drama. It is simply dull hard work. But it is urgent. As H.E. Landsberg, director of climatology of the U.S. Weather Bureau, remarked: "One reliable observation is worth a thousand models and a million speculations." It may well be the master key for unlocking the astrophysical machine that is our sun.

Trudy E. Bell, an editor for ***Scientific American****, is currently working on a book for Scribner's on the history of astronomy in the U.S.*

Why Does Earth's Climate Change?

by
John Gribbin

The timespan involved with astronomical influences on climate ranges from the 200 to 300 million years it takes Earth to orbit once around our galaxy to the yearly change of our seasons. At one extreme, the influences that take millions of years are vague and inconclusive — and of little importance on any human timescale. At the other, the regular cycle of the seasons is so familiar that it needs no elaboration — just a reminder that this seasonal pattern is a very dramatic change and that it is certainly astronomically influenced.

Between the extremes lies a fascinating wealth of ideas concerning the way Earth's climate is molded by changing astronomical influences. Only in the past year has persuasive evidence been found to show that the most recent ice ages were indeed caused by changes in the orbital parameters of Earth. Following this reassessment of one astronomical theory of climatic change, studies are continuing to determine whether effects linked with the sunspot cycle, as well as possible longer solar cycles, can account for changes in climate over tens and hundreds of years. This would be the same as astronomical models that explain the variations over thousands and tens of thousands of years. Climatologists have even questioned whether the sun, long thought to be stable in its energy output, might vary its output by one or two percent over the 11 year solar cycle — with the dramatic implication that perhaps our sun is not, by the old definition, a "normal" star.

But this is getting ahead of the story. Instead, let's start with the longest timescale effects and work down to the changes of recent history because those long-term effects — vague though the theories are — might have some bearing on recent history after all.

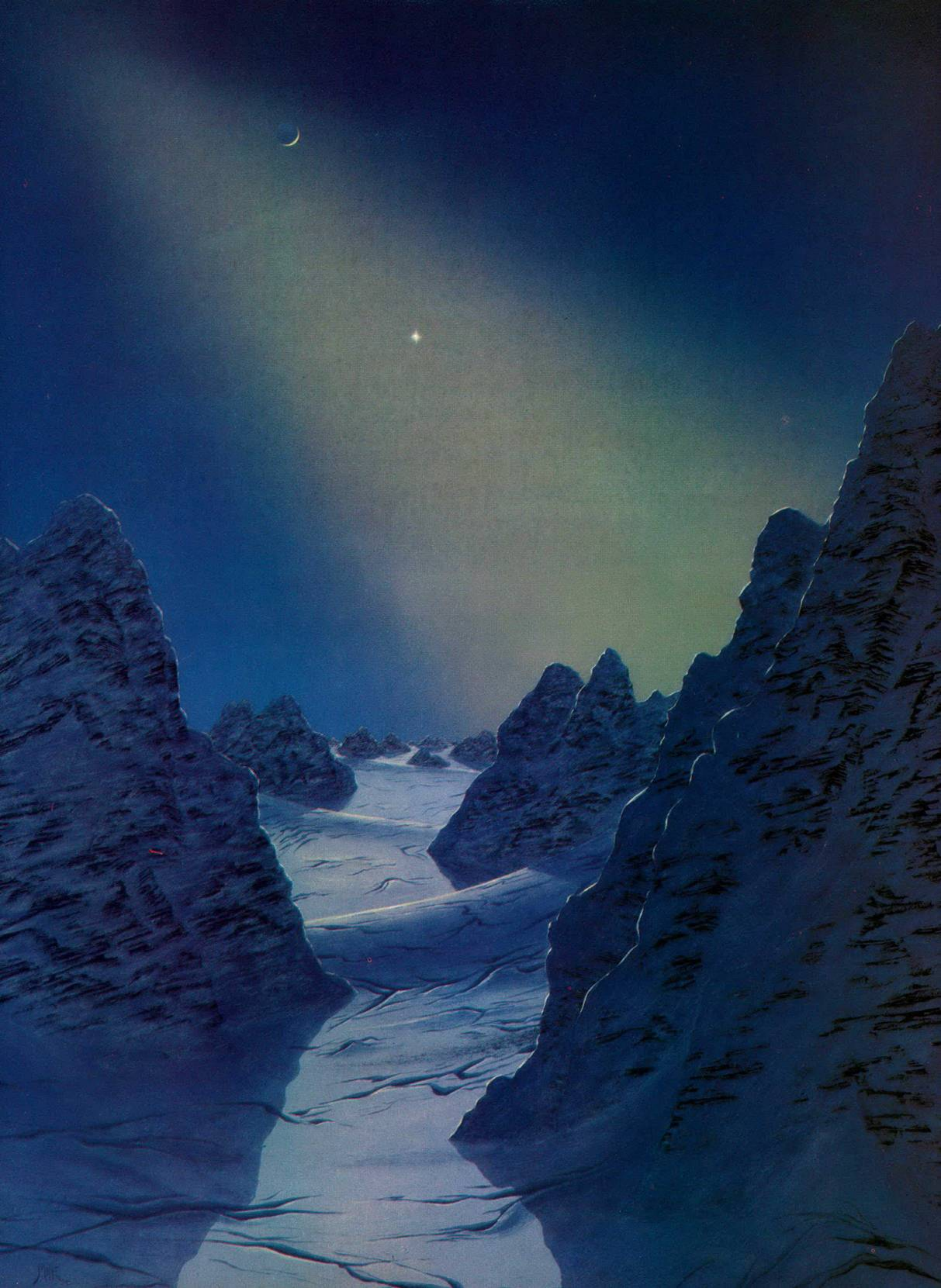
The idea that the passage of the solar system through clouds of dust in space could affect the sun and climate of Earth is an old one, going back a half century or so. In its modern form, the concept depends on the discovery that dark lanes of dust and gas edge the spiral arms of our galaxy, and of all spirals. Any effect of interstellar dust on climate will show up with a regular rhythm as we pass through the spiral arms. That's pretty dramatic theorizing, and although the present knowledge of just how many hundreds of millions of years there should be between these "cosmic seasons" is scanty, it is certainly an interesting coincidence that there seems to be a 200 million year cycle of recurrence of ice epochs on Earth. Epochs each last for about 100 million years, with several full ice ages and several periods of relative warmth within them. Is it really any coincidence that we seem to be living in the tail end of an ice epoch, and that the solar system has just emerged from the dusty gas clouds edging the Orion spiral arm?

Though such speculation is grand, it has no practical value. In human terms, explaining ice epochs is less important than understanding the changing climate *within* ice epochs. Why have full ice ages followed a pattern of advance and retreat over the past million years or so? Was the ice age that ended some 10,000 years ago really the end of the whole ice epoch, or is there another cold period ahead for humans?

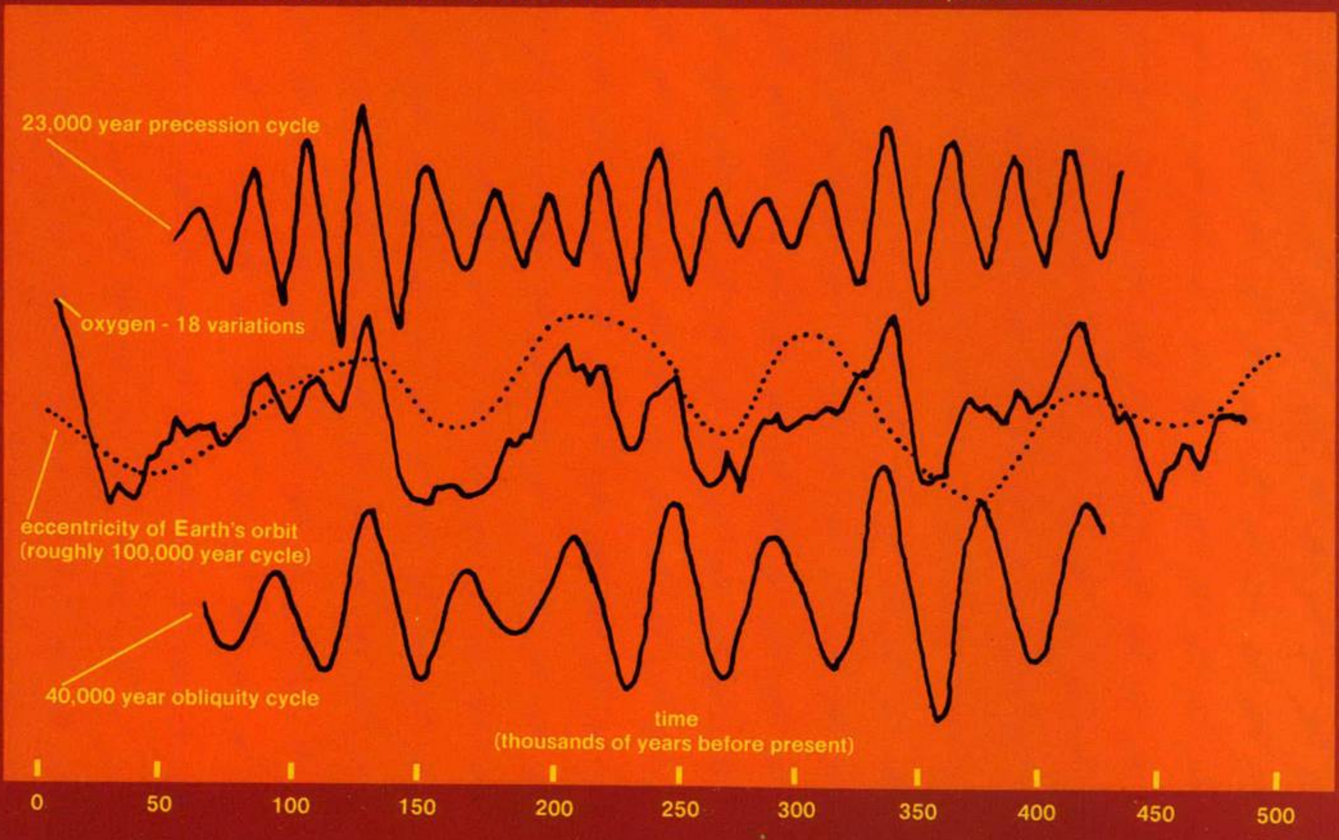
Another astronomical theory that's getting lots of attention is an old one (over a half century old in its original form). It deals with changes in the ellipticity of Earth's orbit and the tilt of its poles toward or away from the sun which can cause major changes in climate. The idea was first advocated in its full form about 40 years ago by Yugoslavian astronomer Milankovitch (for whom the theory is named).

The Milankovitch model is simple, but has required a revolution in our understanding of Earth sciences. Three separate cyclic changes in Earth's movements through space combine to produce

An evening in spring during the next ice age finds only the peaks of Wyoming's Grand Teton Mountains above the glacier. The cosmic dust, hypothesized to be the cause of the climate change, greatly enhances the zodiacal light, seen here with the crescent moon in conjunction with Venus. Because of the large masses of ice spreading across much of Earth, its surface reflectivity is greater and the moon's Earthshine is more apparent. Artwork by Mark Mille.



Variations in Earth's Climate and Orbit for 500,000 Years



By using core samples of ocean floor sediments, scientists have been able to show that climate variations have correlated with Earth's orbital changes. This diagram shows how the oxygen-18 concentration (a measure of ocean temperature) varies with periods of 23,000, 42,000, and 100,000 years. The curves (also known as the Milankovitch cycles) may be used to predict Earth's climate in the future. This diagram was adapted from one published by J. Hayes, J. Imbrie and N. Shackleton in *Science*, Vol. 194, pg. 1121, Dec. 10, 1976; copyright 1976 by the American Association for the Advancement of Science.

overall changes in the solar radiation falling on Earth, which are viewed as a key to the ice ages. First, in a cycle just over 100,000 years long, Earth's orbit "stretches" from elliptical or nearly circular and back again. The more circular the orbit, the more even the spread of heat over the year, with little difference between the seasons.

Second, there is a cycle some 40,000 years long during which the tilt of the spinning Earth changes, "nodding" up and down relative to an imaginary line joining the centers of Earth and the sun. When the tilt is more pronounced, the difference between seasons is enhanced, since the pole tilted toward the sun in summer gets a lot of heat, while the other pole experiences a cold winter.

Finally, the gravitational pull of the sun and moon on Earth's bulging equator produces a wobble like that of a spinning top, with a period between 20,000 and 25,000 years — the cause of the "precession of the equinoxes".

Why should such changes in tilt, wobble and stretch cause the advance and retreat of ice ages? Again, the idea is simple in outline. In the northern hemisphere, with a lot of land around the poles, cold summers mean that snow which fell in winter will lay around without melting, eventually building up as ice sheets and glaciers. In the southern hemisphere, where the polar continent of Antarctica is surrounded by water, the way to build up ice is to have very severe winters, which freeze the water. And since all the Milankovitch effects work in the opposite direction as far as hemispherical seasons are concerned, cold northern summers always coincide with severe southern winters — to produce ice ages!

It took so long to prove the theory that until a few years ago we just didn't have any good idea of how the pattern of the global ice cover had changed in the past million years. Since Milankovitch predicted a whole series of ice ages, separated by warmer "interglacials" (like our present weather), and geologists thought there had only been a couple of ice ages, they dismissed his theory.

However, over the last few decades each improvement in our interpretation of the record of past climates has nudged the evidence closer in line with the Milankovitch model.

The latest and most crucial evidence comes from studies of temperature changes revealed by analysis of cores drilled from the ocean bed around Antarctica. Workers at the Lamont-Doherty Geological Observatory in New York have been instrumental in the development of this technique, which involves studying the remains of sea creatures — planktonic foraminifera — laid down each year on the ooze of the ocean bed. The shells left behind when these creatures die tell us which creatures were around at which times (corresponding to different depths in the sediment layer). That concept already hints at temperatures of the past, since foraminifera have their own favored temperature habitats, just as polar bears or tropical monkeys do.

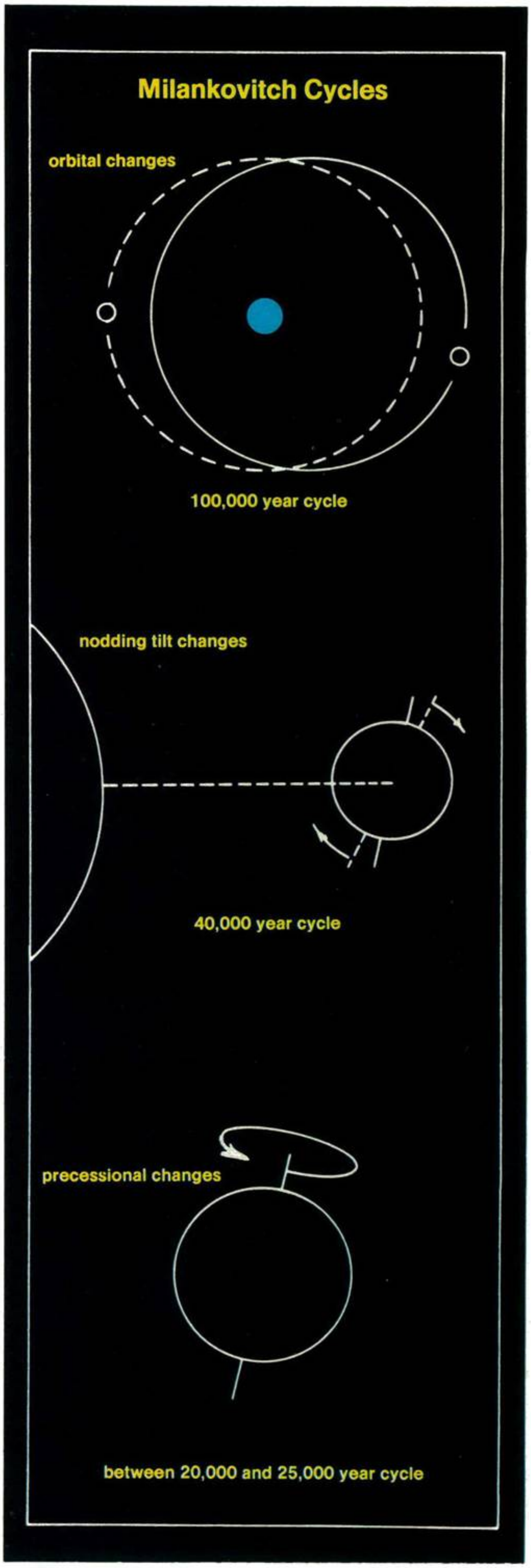
But the best temperature record comes from measures of the ratio of oxygen isotopes in those chalky shells. Oxygen (O) in the atmosphere, and in ocean waters, is mainly O_{16}, with a lacing of a slightly heavier atom (O_{18}) containing two extra neutrons in its nucleus. Because water molecules containing the heavier O_{18} don't evaporate as easily as the lighter ones containing O_{16}, it's easier for them to "stick" on a growing ice sheet and get trapped in the ice. As a result, the proportion of O_{18} left to be taken up in foraminifera depends on the extent of ice cover — and that proportion can now be measured in their tiny remains drilled from the ocean bed.

All this requires a lot of expertise and some sophisticated techniques for measuring the individual isotopes present in the remains. But according to a report by Dr. Jim Hays and his colleagues at Lamont (**Science**, Vol. 194, pg. 1121, Dec. 10, 1976; copyright 1976 by the American Association for the Advancement of Science), the results are clearcut:

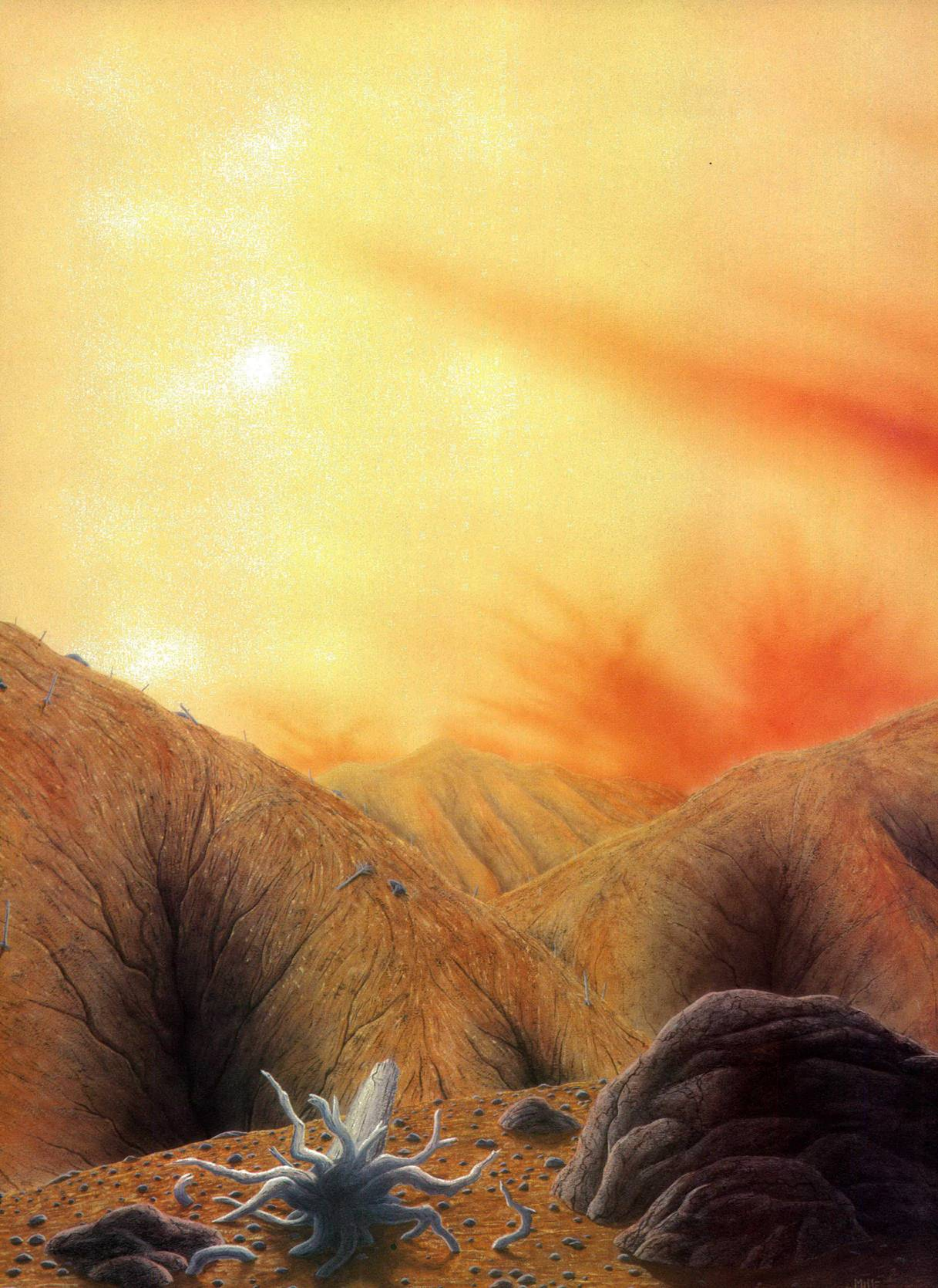
"There can be no doubt that a spectral peak centered near a 100,000 year cycle is a major feature of the climatic record . . . dominant cycles . . . range from 42,000 to 43,000 years (and) three peaks . . . correspond to cycles 24,000 years long."

These, of course, are the Milankovitch cycles. That immediately gives us a "long range forecast", since the three cycles can be extended forward to tell us how climate will vary over the *next* 10,000 years.

At present, we are living in an era of low orbital eccentricity; the three Milankovitch effects got together to change us from a full ice age 18,000 years ago to an ice minimum 6,000 years ago; now things are moving away from this favorable state. Probably for the next 50,000 years — and certainly the next 10,000 years — the orbital changes are going to be working in favor of the ice. The "next" ice age has already started to develop, and may well arrive before that 10,000 year period is over.



This diagram (not drawn to scale) illustrates the concept of the three cyclic changes that make up the Milankovitch cycles. The top portion shows how Earth's orbit stretches in a 100,000 year cycle from circular to elliptical and back again. The center portion of the diagram shows how the tilt changes every 40,000 years, using an imaginary line drawn from the center of Earth to the center of the sun. The lower portion shows the wobble that is produced by the gravitational pulls of the sun and moon, making Earth spin like a top. Artwork by Mark Paternostro.



It's certainly something of crucial importance to the whole human race, but unlikely to make much difference in our own lifetimes. Most of us don't look farther ahead than a few years, and even astronomers, used to thinking in terms of long timespans, are more likely to worry about the climate of the next decades than that of the next millennium. So, how can we bring the astronomical climate story down to a human timescale?

The best and most up-to-date evidence comes from studies by Dr. John Eddy (see Astro-News, May and October 1976) and others at the National Center for Atmospheric Research (NCAR) in Boulder, Colo. Eddy has made the most critical examination ever of historical records which show that during the 17th century — a period so cold on Earth that it has been dubbed "the little ice age" — the sun was peculiarly inactive, with few (if any) sunspots and no 11 year cycle of activity. Dr. Stephen Schneider (deputy head of the climate project at NCAR) and Clifford Mass, a graduate student in atmospheric sciences, have brought the story up-to-date with studies suggesting that the temperature changes on Earth *since* the 17th century have depended on the average level of solar activity — not the activity associated with sunspots on a year-to-year basis, but the differences between one 11 year cycle and the next.

These results provide a really good fit with actual temperature changes. The little ice age is most prominent, of course, but the cool years early in the 19th century, the warming in the early part of the 20th century, and the cooling we have experienced in the past two decades are all explainable on this basis.

The snag is that it implies a variation of as much as two percent in the output of energy from the sun on the timescale of the 11 year cycle of solar activity!

This alone is why the theory remains controversial. All our observations of other stars suggest that the sun should not vary by so much in such a short time. But to the embarrassment of many astronomers, Schneider, a climatologist, has pointed out that we have no long-term studies of solar output accurate enough to tell us if our sun is a two percent variable on a timescale of 11 years. In fairness, however, it's even now a difficult task to make measurements accurate to two percent over a decade. Other stars can be compared with one another to monitor brightness changes — but with what can we compare the sun? Can observations made through the atmosphere (which changes from one day to the next) be trusted — let alone those spanning a decade? What is needed — urgently — is a monitoring experiment onboard a satellite above the atmosphere. But such an experiment would have to continue operating for at least 11 years to be worthwhile — and even today that's pushing space technology to the limit.

Meanwhile, the solar activity/climate theory provides us with another forecast. Using the best "guesstimates" about solar cycle variations, most astronomers expect the recent strong sunspot cycles to be followed by a calmer pattern more like that of the early 19th century. That would mean, if not another little age ice, at least some pretty severe winters. The winter of 1976-77 may have been a taste of things to come in North America.

For astronomers, however, the other side of the theory is equally interesting. How could the sun vary in the way the climate model seems to indicate? Curiously — and perhaps significantly — we already have some evidence that our sun may not be all it seems. The continuing puzzle of the absence of solar neutrinos, for example, is most easily explained if the sun has gone "off the boil" temporarily, cooling down in the interior by about 10 percent or so. Can stars go off the boil? Can nuclear fusion halt inside the sun for a few million years (certainly a short period in its lifetime)? If so, what could cause the change?

Remember McCrea's revival of the idea of a link between ice epochs and dusty material in space. Remember too that within the past 100,000 years — the blink of an eye by solar standards — we have emerged from the gas and dust edging the spiral arm. Could the effect of the passage through that dust have disturbed the sun's equilibrium, upsetting the convection process inside which is now returning toward equilibrium, and thereby readjusting its interior making it prone to rather unusual small scale fluctuations as a result? Here, if anywhere, lies the solution to the puzzle of whether the sun is in a normal state today. Dust falling on the sun might act like a lid on a pan of boiling water; remove the lid (or dust) and the water (or sun) takes a little while to settle in its usual stable state. It's just that for a star like our sun, a "little while" might be a few million years!

It may be speculation, but the idea does at least suggest a neat link between the longest term astronomical influences on climate and the changes which are more urgent on a human timescale. And remember, the cause of these changes does not alter the prediction. In light of our best understanding of astronomical influences on climate today, we can expect 10 or 20 years of harsher weather than we have been used to in our lifetimes. Exactly what will happen after the turn of the century is harder to foretell — but then, within the next few thousand years, the certainty of a new ice age lies in the future of Earth.

Should Earth experience the climatic "greenhouse effect", ecological changes could be catastrophic. Here we see a duststorm approaching along the gullied crests of Virginia's once lush Blue Ridge Mountains, from which the vegetation has burned away. Artwork by Mark Mille.

John Gribbin is a member of the Science Policy Research Unit at the University of Sussex, England. He has written several books on astronomy and Earth sciences, including ***Our Changing Planet*** *(Crowell, New York).*

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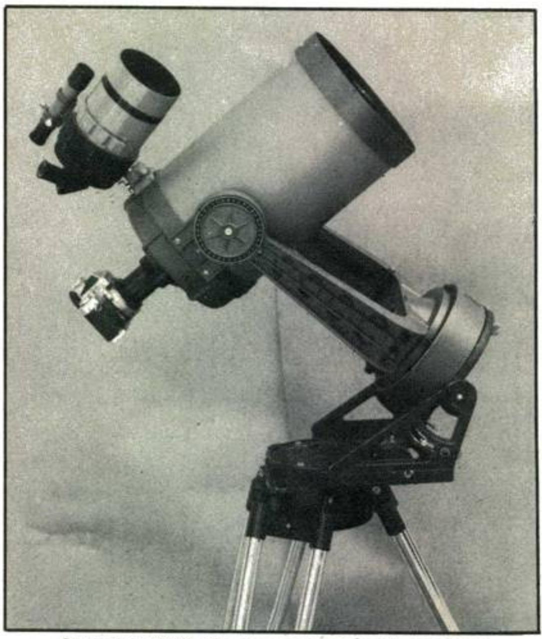

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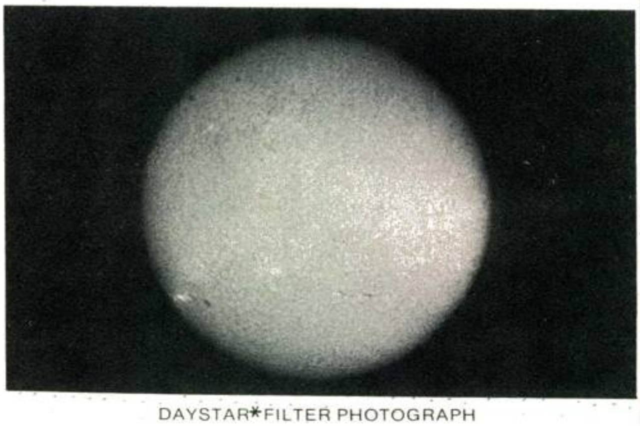

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Saturnshine

February Satellites of Jupiter
12:00 p.m. EST, 9:00 p.m. PST

1	32014	• • ● •	16	32014	• •● •
2	310	• • ●	17	024	● • •
3	40312	• ●•• •	18	1043	•● • •
4	41203	• • •● •	19	24013	• •● • •
5	42013	• • ● • •	20	4103	• • ● •
6	41032	• • ●••	21	43012	• • ● • •
7	43012	• • ●••	22	43210	• • ••●
8	4320	• • • ●	23	43201	• • •●•
9	43120	• • • •●	24	402	• ● •
10	40321	• ●•• •	25	41023	• •●• •
11	1043	• ● • •	26	42013	• • ●• •
12	20134	• ● • ••	27	103	• ● •
13	10324	• ● •• •	28	30142	•●•••
14	30124	• ●•• •	29		●
15	32104	• • •● •	30		●

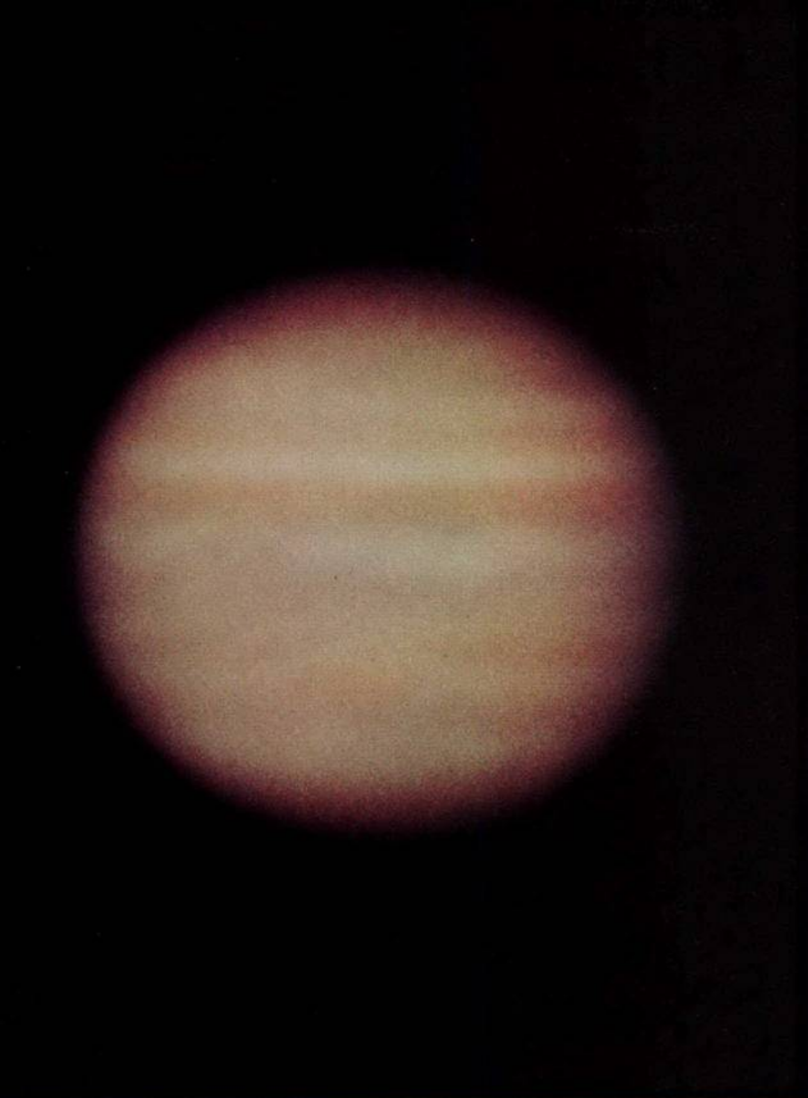
The four major satellites of Jupiter orbit the planet in periods ranging from less than two days to 17 days. You can see them change position from one night to the next; their motions are often evident after only a few hours' observation. You only need a small telescope to detect all four, and you can frequently make out several in rigidly held (or tripod mounted) binoculars. This table shows the approximate positions of the moons at about 12 p.m. EST on the mornings indicated. The first column on the left shows the date; the second column identifies the moons by their positions relative to Jupiter's disk (1 =Io, 2 =Europa, 3 =Ganymede, 4 =Callisto, 0 =Jupiter's disk). The third column gives the satellites' positions as they appear through a telescope. The orientation of the satellite is given with south up as seen through a standard inverting telescope.

For the third consecutive month, one of the bright outer planets comes to opposition as Saturn follows Jupiter and Mars across the winter sky. During the first days of February, these three planets provide an interesting view as they are equidistantly spaced along the ecliptic. The return of Venus, the brightest planet, to the evening sky completes the February picture.

Saturn

Saturn reaches opposition on Feb. 15 at 11 p.m. EST. It will be exactly opposite the sun in the sky, with Earth directly between the two. Saturn will

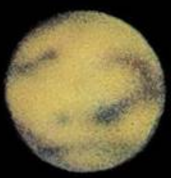
Top left: Jupiter leads the way across the winter sky this month. In this photograph you can distinguish between the light and dark bands that run parallel to the equator. These cloud bands exhibit gradual changes which indicate that they are atmospheric phenomena. This photograph was taken using a 14 inch Celestron at f/100; the exposure was four seconds on High Speed Ektachrome at ASA 160. Photograph by James K. Rouse. Top right: Saturn reaches opposition this month, so this is a good time to photograph it. This shot is a four second exposure on High Speed Ektachrome taken with a 16 inch Schmidt-Cassegrain (18mm eyepiece) using eyepiece projection. Photograph by Steven Wissler. Bottom: Events in the sky can be combined with scenes on Earth to yield an attractive photograph. Here we have a faint Mars shown .1 degree north of the moon, and Venus which is two degrees south of the moon as the approaching sun colors the morning sky. This 30 second exposure on Kodachrome 64 was taken with a 35mm camera on a tripod using a 40mm lens at f/1.7. Photograph by Fred Espenak.

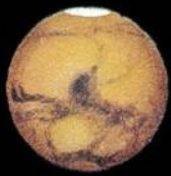


Planet Finder

Ⓒ Ceres

Feb.	1	15
R.A.	$17^{h}55^{m}$	$18^{h}17^{m}$
Dec.	-22°40'	-23°02'
Mag.	+8.2	+8.2





Ⓐ Mercury

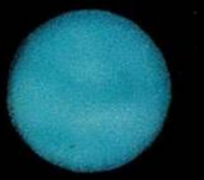
Feb.	1
R.A.	$19^{h}46^{m}$
Dec.	-22°22'
Mag.	-0.2

Ⓑ Mercury

Feb.	15
R.A.	$21^{h}19^{m}$
Dec.	-17°48'
Mag.	-0.7

Ⓜ Mars

Feb.	1	15
R.A.	$8^{h}03^{m}$	$7^{h}45^{m}$
Dec.	+24°55'	+25°25'
Mag.	-1.0	-0.6



Ⓝ Neptune

Feb.	15
R.A.	$17^{h}08^{m}$
Dec.	-21°27'
Mag.	+7.7

SUN

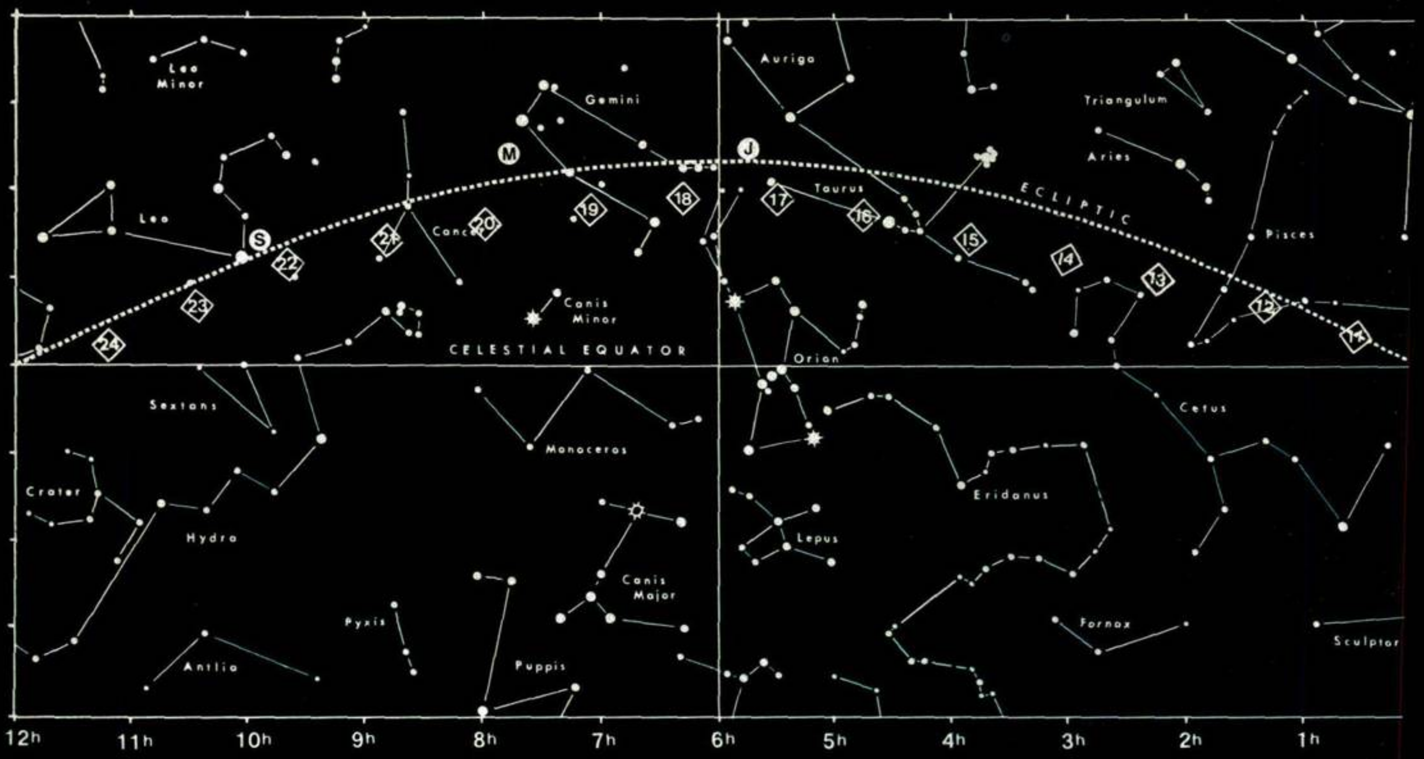
The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.

Ⓢ Saturn

Feb.	1	15
R.A.	$10^{h}04^{m}$	$9^{h}59^{m}$
Dec.	+13°28'	+13°52'
Mag.	+0.4	+0.3

Ⓤ Uranus

Feb.	15
R.A.	$14^{h}56^{m}$
Dec.	-16°21'
Mag.	+5.7

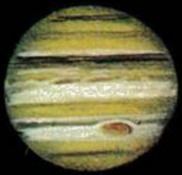

Leo Minor
Gemini
Auriga
Triangulum
Aries
M
J
Leo
S
Cancer
Taurus
ECLIPTIC
Pisces
24
23
22
21
20
19
18
17
16
15
14
13
12
11
Canis Minor
CELESTIAL EQUATOR
Orion
Sextans
Cetus
Monoceros
Crater
Eridanus
Hydra
Lepus
Canis Major
Pyxis
Fornax
Sculptor
Antlia
Puppis
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h

The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec . = *declination, the two coordinates used to locate* astronomical objects. The general coordinate system is indicated around the edge of the map. Mag . = magnitude, a

February 1978

Ⓥ Vesta

Feb.	1	15
R.A.	15^h53^m	16^h16^m
Dec.	-13°40'	-14°28'
Mag.	+7.0	+6.9



Ⓙ Jupiter

Feb.	1	15
R.A.	5^h45^m	5^h43^m
Dec.	+23°14'	+23°15'
Mag.	-2.2	-2.1

Ⓨ Venus

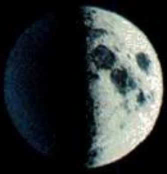
Feb.	1
R.A.	21^h07^m
Dec.	-17°48'
Mag.	-3.5

Ⓩ Venus

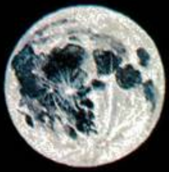
Feb.	15
R.A.	22^h16^m
Dec.	-12°13'
Mag.	-3.4

Ⓟ Pluto

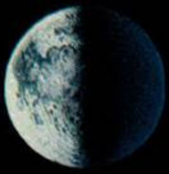
Feb.	15
R.A.	13^h26^m
Dec.	+9°46'
Mag.	+14



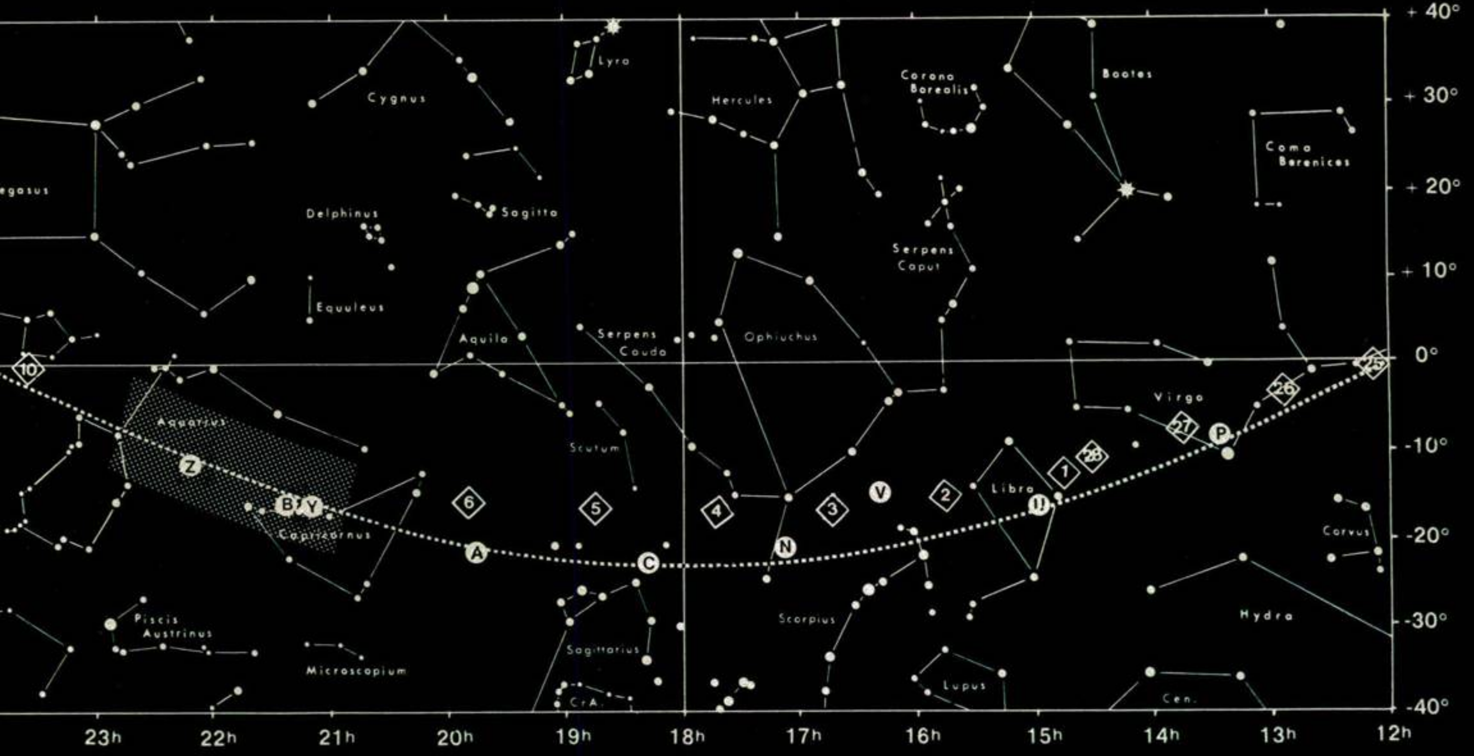
First Quarter
February 14



Full Moon
February 22



Last Quarter



+40°
+30°
+20°
+10°
0°
-10°
-20°
-30°
-40°
23h
22h
21h
20h
19h
18h
17h
16h
15h
14h
13h
12h
egasus
Cygnus
Lyra
Hercules
Corona Borealis
Bootes
Coma Berenices
Delphinus
Sagitta
Equuleus
Serpens Caput
Aquila
Serpens Cauda
Ophiuchus
Virgo
Aquarius
Scutum
Libra
Capricornus
Corvus
Piscis Austrinus
Microscopium
Sagittarius
CrA
Scorpius
Lupus
Hydra
Cen.
Z
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25

measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.

rise at sunset, remaining in the sky all night until it goes below the horizon at dawn.

Opposition is the best time to observe any of the outer planets because they are brightest and nearest Earth when they reach that point. On the 15th, Saturn will lie 766 million miles (1,231 million kilometers) from Earth and shine at magnitude +0.3 — a full magnitude brighter than the star Regulus, near which Saturn is located in the constellation Leo.

Satellite Shadows on Jupiter

Date	Satellite	Transit Begins (EST)	Transit Ends (EST)
Feb. 1	1	4:22 a.m.	6:36 a.m.
2-3	1	10:51 p.m.	1:04 a.m.
4	1	5:20 p.m.	7:33 p.m.
5	2	1:50 a.m.	4:30 a.m.
10	1	12:46 a.m.	2:59 a.m.
12	1	7:15 p.m.	9:28 p.m.
12	2	4:27 a.m.	7:07 a.m.
14	3	5:28 p.m.	8:31 p.m.
15	2	5:46 p.m.	8:26 p.m.
18	1	9:10 p.m.	11:23 p.m.
21-22	3	9:28 p.m.	12:32 a.m.
23	2	8:23 p.m.	11:02 p.m.
24	1	4:36 a.m.	6:50 a.m.
25-26	1	11:05 p.m.	1:19 a.m.
27	1	5:34 p.m.	7:48 p.m.

1 = Io
2 = Europa
3 = Ganymede
4 = Callisto

Saturn is not as bright at this opposition as it has been in recent years, primarily because its magnificent ring system is *closing*. Saturn's rings rotate the planet exactly in its equatorial plane, and the respective orbits of Earth and Saturn take our planet through this plane twice during Saturn's 29-1/2 year trip around the sun. The next time this will happen is in 1980; at that time, the rings will be seen edge-on and virtually disappear from view. As the ring system closes during these years, it reflects less light to Earth, and Saturn will appear dimmer.

If you're observing Saturn through a small telescope and exclaiming over the beauty of its rings, be sure to tear yourself away for a few minutes to observe some of Saturn's moons. The brightest, Titan, will be seen best on Feb. 5 and 21, when the satellite will be at eastern elongation (the point in its orbit at which it is farthest east of Saturn as seen from Earth), and on Feb. 13 and March 1, when Titan is at western

Opposite: This is a rather unusual view of the constellation Orion, showing it as one large bunch of star trails. The odd looking streak in the photo is an airplane, and the bright streak it crosses is Saturn. This is a 2-1/2 hour exposure on High Speed Ektachrome using a 35mm camera at f/2. Photograph by Scott Davis. Above: Jupiter makes a pretty picture with the Pleiades (M-45) in this 10 minute exposure on 103aE film. A 35mm camera used with a 135mm lens at f/2.8 was guided piggyback on an eight inch Schmidt-Cassegrain. Photograph by Tom Koed.

elongation. Look for an eighth magnitude point of light near the planet. Saturn's other moons can be seen in larger aperture instruments.

On the morning of Feb. 22, look for Saturn five degrees north of the nearly full moon. Saturn will be moving through Leo for the rest of 1978.

Mars

Still moving retrograde after reaching opposition last month, the red planet crosses back from Cancer into Gemini early in February. It will line up with the "twin" stars Castor and Pollux on Feb. 8, and will lie only three degrees south of Pollux on the morning of the 17th.

Mars drops in brightness after opposition faster than any other planet because it's the nearest of the outer planets, and retreats from Earth a greater distance in a shorter period of time than the others do. During February, Mars' magnitude will plummet from -1.0 to -0.3 as its distance increases from 62 million miles (76 million kilometers) on Feb. 1 to 100 million miles (122 million kilometers) by month's end.

Although it drops rapidly in brightness, Mars still outshines almost all the stars during February. Look for it nine degrees north of the waxing gibbous moon on the evening of the 19th.

Jupiter

The brightest of the three planets that grace this month's night sky, giant Jupiter shines at magnitude -2.1 in the easternmost section of the constellation Taurus, located just a little too far east to be between the "horns" of the bull (Zeta and Beta Tauri). The planet is stationary on Feb. 19 and resumes direct motion (as opposed to retrograde) thereafter.

Jupiter's distance from Earth increases from 410 million miles (659 million kilometers) to 444 million miles (715 million kilometers) during the month. Its brightness drops very slightly.

Jupiter lies practically overhead for observers in midnorthern latitudes (including most of the United States) early on February evenings, so while opposition in December may theoretically have been a "better" time to see Jupiter, now is certainly more convenient (at least for most people). The planet will lie five degrees north of the waxing gibbous moon on the morning of the 17th.

Mercury, Venus

Mercury will be too close to the sun to be seen all month; superior conjunction occurs on Feb. 26. Venus, just emerging from superior conjunction in January, will appear very low over the western horizon after sunset. You'll get a much better view of the planet later this year; see "Observing Venus" in this month's Gazer Gazette for tips on seeing the planet. Venus shines at magnitude -3.4 in February and lies 158 million miles (254 million kilometers from Earth.

ASTRONOMY

Index to Volume 4, 1976

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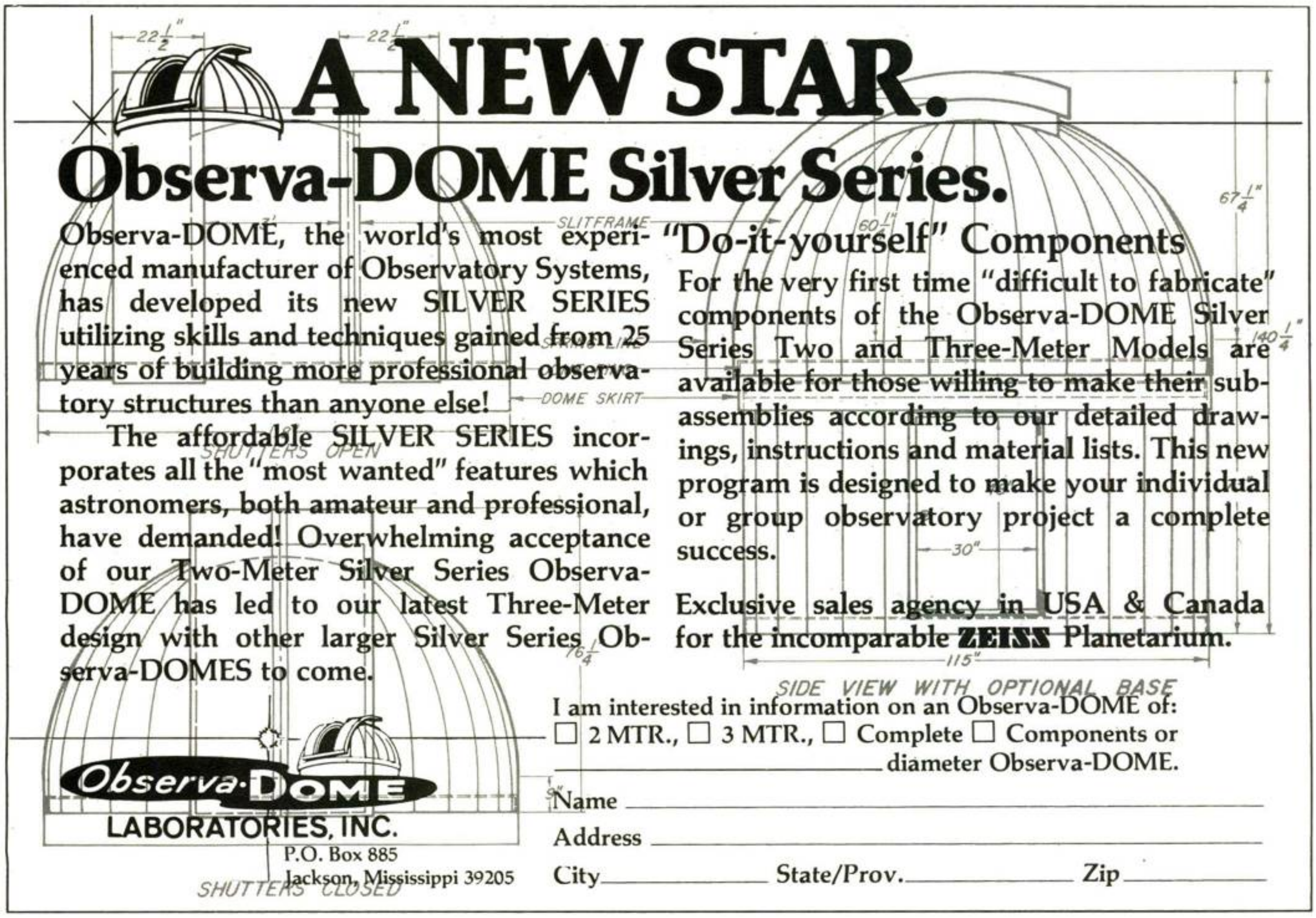

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1.	3" Unitron Folded Optical Path Refractor	$660
2.	1¼" Eyepiece Adaptor	No Charge
3.	Freight UPS Continental U.S.	No Charge
4.	Certificate for Special Discounts on Selected Accessories	No Charge
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CHRISTMAS PACKAGE #10

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3.	Certificate for Special Discounts on Selected Accessories	No Charge
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CHRISTMAS PACKAGE #12B

1.	Celestron C-8 Telescope	$785
2.	Wedge	39
3.	Micro-Fine Latitude Adjustor	No Charge
4.	Weatherproof Accessory Case	No Charge
5.	Freight UPS Continental U.S.	No Charge
6.	Certificate for Special Discounts on Selected Accessories	No Charge
	TOTAL	$824

CHRISTMAS PACKAGE #15

1.	8" Celestron C-8 Telescope	$785
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5.	Tripod	118
6.	Micro-Fine Latitude Adjustor	No Charge
7.	Weatherproof Accessory Case	No Charge
8.	Freight UPS Continental U.S.	No Charge
9.	Certificate for Special Discounts on Selected Accessories	No Charge
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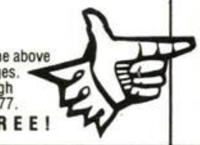

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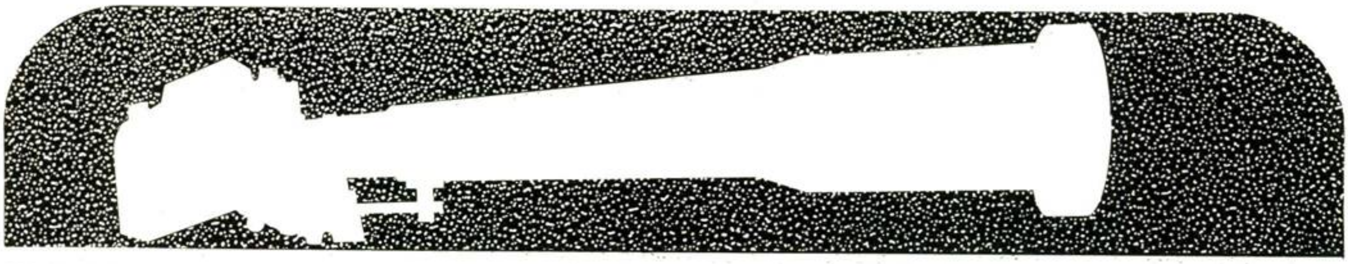


PHOTOGRAPHY IN ASTRONOMY

Photograph the Moon!

by
Richard Berry

The moon is the "first and last" subject for every astrophotographer: No other celestial body is so easy and satisfying a target for your first ventures into sky photography; no other object yields a new face every night of the month, and no other subject you can turn your camera toward elicits so much admiration from your nonsky-minded friends.

You can photograph the moon with nearly any kind of photographic or telescopic gear; there are almost no limits. Of course, what you'll get will depend on the camera and telescope you use, but you'll find satisfaction at every level of sophistication.

The basic problems of lunar photography can be solved by answering two questions: How bright is the moon, and how big is the image of the moon on your film? The answers are surprising. The moon is a darkish object lit by a principal light source (the sun), so that the proper exposure for taking a good moon shot is about one f/stop more than it is for a daytime terrestrial scenic! "What? But don't you see the moon at night?" you might wonder. Of course! But the moon is not in Earth's shadow as we Earth-dwellers are — it's still in bright sunshine out there in space. If you want to take a picture of the moon, a good starting exposure is the same exposure and f/stop you'd use for a "cloudy-bright" terrestrial scene. (Since the moon is rather dark — about the brightness of an asphalt driveway — it needs "cloudy-bright" rather than "sunny-bright".)

The second answer usually knocks photographers for a loop. How big is the lunar image? Just divide the focal length of the camera by 115 and you'll have your answer. So a supertelephoto lens — like a 400mm — will give you a lunar image of just 400 divided by 115, or 3.4 millimeters across (about 1/8 inch). Clearly, even a very large blowup is going to yield a small moon, only an inch or two across! You'll need a focal length of at least 1,000mm to see more than the biggest craters and mountains, and for the ultimate in fine detail, the focal length has to be in excess of 20,000mm. That's quite some lens!

But before getting carried away with snazzy equipment, let's consider for a moment just what you're after in lunar photography.

Types of Lunar Photography

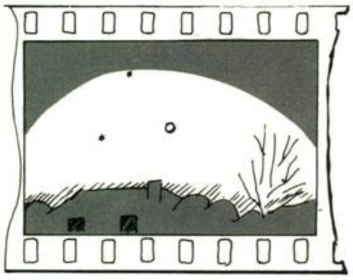
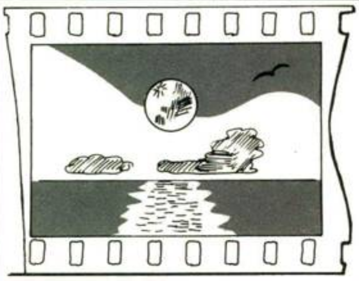
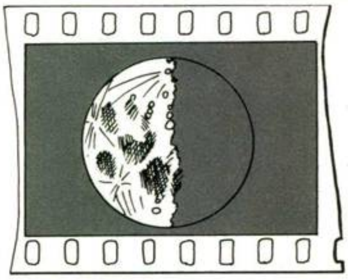
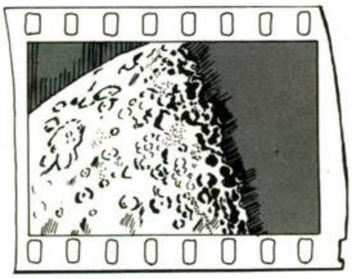
First, your moon can be a romantic or esthetic moon — seen against a horizon or trees, or with other celestial objects such as bright planets spread gloriously across the dawn sky. Whether a romantic moon can properly be called *astro*photography doesn't really matter; what matters is the image.

Next, more powerful lenses and small telescopes bring you a small sized moon that's big enough to show the lunar maria and some of its largest craters. Hanging over a landscape, it's dynamite — and in terms of what it shows about the moon, Galileo saw about as much with his first telescopes! You'll feel a bit like a lunar explorer when you resolve your first craters. Events like occultations and close approaches to star clusters, planets or bright stars, and effects like "the old moon in the new moon's arms", record well in small size lunar images.

Bigger still are "full moon" pictures, made with lenses or telescopes that can record the entire lunar disk with a focal length long enough that the moon fills all or most of the film frame. The moon is about 18 millimeters (3/4 inch) across — large on a 24x36mm frame of 35mm film. When blown up 10 times, the lunar image fills an 8x10 glossy! At this size, you can see how the entire lunar disk looks — where the maria are and some of their details, craters with rumpled rims and central peaks, bright spots when the moon's full — and see all the features of an entire little "planet" at one glance. Full moon pictures look great on the wall in your study or bedroom and, if they are sharp and grainless, are fabulous for studying just for the fun of it.

Finally, there are the detail shots which take in anything from 1/2 to 1/20 of the lunar disk — the goal being to record the tiniest details that the optics and atmosphere will allow. Four inch refractors and six inch reflectors are the smallest telescopes that can play this kind of game. The general rule is

Types of Lunar Photography

Type	Range of Focal Lengths	What You'll Get	Sample Frame
"Romantic" Moon	28 to 100 millimeters	• a tiny image of the moon • foreground objects such as trees and horizon • other astronomical objects nearby in the sky	
Small sized Moon	135 to 500 millimeters	• an image large enough to show maria and large craters • dramatic images when a horizon foreground is used	
"Whole Moon"	1,000 to 2,500 millimeters	• a frame-filling lunar image • hundreds of craters and other lunar features all together in one shot • record of the lunar phases	
Detail Closeup Moon	5,000 to 40,000 millimeters	• detailed images of small parts of the moon • under good conditions, everything the telescope can reveal • pictures useful for study and learning about the moon	

"the bigger the better" up to 60 or 80 inch telescopes; after that, it doesn't matter much!

Exposure

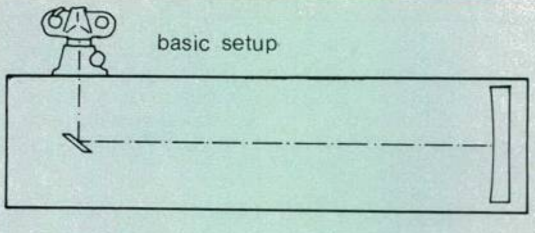
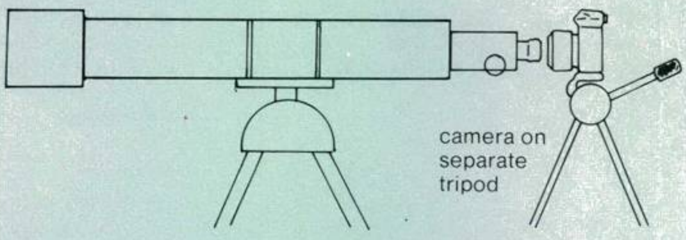
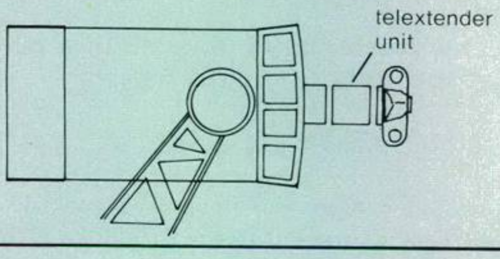
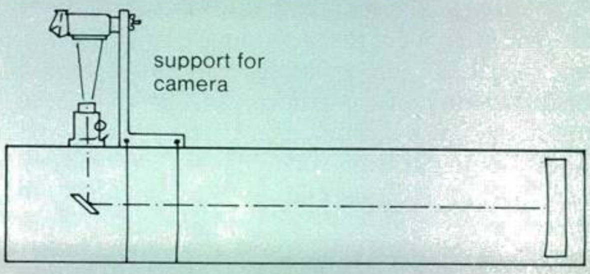
As mentioned earlier, the moon is essentially a rather dark object sitting out in the full glare of the sun. Full sunlight photography is a photographer's paradise, so lunar pictures should pose no exposure problem at all. If you're doing romantic, small moon or full moon pictures, there usually won't be a problem. In each case, the f-ratio of the camera approximates the usual range of daytime f-ratios; typical exposures of 1/60 second at f/8 on ASA 64 film work equally well for flowers, mountains and the moon. Your trusty telephoto lens, a small refractor or your homemade reflector have f-ratios reasonably close to f/11 — such as f/6.3, f/15 and f/10 — so you can just set your exposure times to 1/125, 1/15 and 1/60 respectively.

But what happens when you want a bigger image? Since the f-ratio is the focal length divided by the lens aperture, increasing the focal length (which we'll get to later) to give a bigger image with more detail means the focal ratio gets larger, and the images get dimmer. For a perfectly reasonable f-ratio of f/80 with a focal length of 16,000 millimeters (typical for an eight inch telescope), the daytime exposure works out to four seconds on ASA 64 film! Since the moon does move across the sky, all you could record without a fancy clock drive would be a big blur. By using a fast film (ASA 400 to 1600), your exposure drops to 1/2 or 1/4 second, giving a feasible exposure even *without* a clock drive to track the moon. Clearly though, the penalty for a big image is inevitably an exposure time that allows for image motion, wind vibration, atmospheric turbulence, and a dozen other factors that degrade the sharpness of the image. What is called "technique" in lunar detail photography is really avoiding the ill effects, and learning to expose the right length of time, at the right moment, such that the atmosphere, telescope and everything else are just right.

Getting Started: Camera Moons

The moon can be part of the picture with any camera — including Instamatics and box Brownies — as long as you can make a time exposure. The camera should be placed on a tripod (or braced firmly on some steady object). Then compose the view you want on the ground glass or in the viewfinder. Expose for the time indicated by the camera's metering system if the sky is fairly bright or in twilight, or 1 to 10 seconds at f/2.8 if your prime interest is planets and bright stars near the moon. Remember that the moon will be heavily overexposed — but your object is not to record the features of the moon but instead its location in the sky. If the moon is a thin crescent, you'll almost surely record the "new moon in the old moon's arms" next to the overlit crescent. Just for the fun of it, you can try the "cloudy-bright" exposure on a quarter or gibbous moon high in the sky; the result will be a tiny gray circle on your negative. You can probably pick out some of the mare regions if you have a blowup made, but you should regard the whole thing as an experiment rather than a serious moon portrait. If you have a telephoto lens, try some pictures with it: Long lenses can record some of the larger craters and will show maria well.

Combining Telescope and Camera

Method	How to Find the Effective Focal Length (efl)	
Direct	efl = telescope objective's focal length	
Afocal	efl = camera f.l. x telescope power — or — $\text{efl} = \text{telescope focus} \times \left(\frac{\text{camera f.l.}}{\text{eyepiece f.l.}}\right)$	
Negative Projection	efl = telescope f.l. x telextender magnification	
Eyepiece Projection	$\text{efl} = \text{telescope f.l.} \times \left(\frac{\text{projection distance}^{*}}{\text{eyepiece f.l.}}\right)$ * NOTE: This is not exact, but close enough for practical purposes.	

This beautiful full moon image was made at the focus of a six inch f/15 refractor on Kodachrome 64 film, using a 1/4 second exposure. Virtually any telescope with a focal length between 40 and 100 inches can make similarly beautiful images — whether refractor, reflector, cassegrain, or catadioptric. Photograph by Don Primi.

Combining Camera and Telescope

There are four basic ways to bring the lunar image from a telescope to film (see table 2, page 36). Most straightforward is to use the telescope objective to form the image directly on the film; the biggest drawback is usually attaching the camera to the telescope. The obstacle is the eyepiece holder-focuser device which is designed to hold 24.5mm or 1.25 inch standard size eyepieces, but not to allow a 35mm camera to be attached. Adapters are available, but they usually slip-fit into the holder-focuser, and are therefore unstable and wobbly. In recent years, Celestron and Criterion engineered a breakthrough with telescopes that adapt directly to standard camera T-mount fittings. These telescopes function essentially like giant telephoto lenses, and indeed are sold as such. Edmund Scientific has recently joined the easy adapters with their eight inch f/5 telescope with an oversized two inch focuser that adapts directly into T-mount fittings. (See "Astrophotography With Newtonian Reflectors", ASTRONOMY, September 1977, for information if you cannot bring the image to sharp focus.)

The most utilitarian camera-to-telescope coupling for owners of single lens reflex cameras is the *afocal* method. Afocal means nothing more than putting your camera up to the eyepiece instead of your eye to take a picture. For bright objects like the moon, nothing could be simpler. If the exposure turns out longer than 1/30 second, support the camera on a tripod (while it isn't fun moving the tripod all the time to keep up with the telescope's eyepiece, at least your pictures won't be blurred). How big will the lunar image be? First, find the focal length — which is the telescope magnification times the camera's focal length. Your 55mm lens aimed into a 100 power telescope will give you a 5,500mm focal length. To find the lunar size, divide 5,500mm by 115; you'll get 48mm. The lunar image will be bigger than the 35mm film frame and you'll be doing lunar detail pictures. If the telescope is a six inch reflector (150mm), the f-ratio is 5500 divided by 150, or about f/37. If you pop that number into the exposure equation or use the handy look-up table (table 3 on page 39), you'll have a trial exposure for your first shots!

Negative projection involves using a Barlow lens or "telextender" lens to increase the focal length of the telescope objective. It used to be very popular, but has fallen into disuse largely because

Barlow lenses are usually not very sharp. Telextenders are part of many photographers' gadget bags, and are nothing more than fancy achromatic Barlow lenses. To use one, simply snap it to the front of the camera and attach the camera to the telescope via whatever kind of adapter you use for direct photography. They are useful for moderate-detail pictures with telescopes that offer instant camera adaptation.

Eyepiece projection (sometimes called positive projection) is the method to use for lunar detail. If you have ever examined the sun by eyepiece projection, you are familiar with the ability of an eyepiece to form an enlarged image. All you really need to do for high detail lunar photography with eyepiece projection is to put your camera out where the image is the right size, bring it to sharp focus, and then (without shaking the telescope even the tiniest amount) expose the film to the enlarged image for the correct amount of time. A quick approximation for finding the image size involves measuring the "throw distance" of the eyepiece. If you use a 28mm eyepiece with a throw of nine inches (225mm), then the image magnification is roughly 225 divided by 28, or just about eight times. If the telescope is an eight inch f/5 reflector (focal length of 1,000mm or 40 inches), then the focal length of the system is 8,000mm. The lunar diameter will be 8,000 divided by 115, or about 70mm; the f-ratio is 8,000mm divided by 200mm (eight inches), or f/40. Table 3 provides the correct exposures for various lunar phases.

Lunar Exposures

	Film ASA	Full	Gibbous	Quarter	Crescent	Thin Crescent
f/5	25	1/125	1/60	1/30	1/15	1/8
	50	1/250	1/125	1/60	1/30	1/15
	100	1/500	1/250	1/125	1/60	1/30
	200	1/1000	1/500	1/250	1/125	1/60
f/7	25	1/60	1/30	1/15	1/8	1/4
	50	1/125	1/60	1/30	1/15	1/8
	100	1/250	1/125	1/60	1/30	1/15
	200	1/500	1/250	1/125	1/60	1/30
f/10	25	1/30	1/15	1/8	1/4	1/2
	50	1/60	1/30	1/15	1/8	1/4
	100	1/125	1/60	1/30	1/15	1/8
	200	1/250	1/125	1/60	1/30	1/15
f/15	25	1/15	1/8	1/4	1/2	1
	50	1/30	1/15	1/8	1/4	1/2
	100	1/60	1/30	1/15	1/8	1/4
	200	1/125	1/60	1/30	1/15	1/8
f/22	50	1/15	1/8	1/4	1/2	1
	100	1/30	1/15	1/8	1/4	1/2
	200	1/60	1/30	1/15	1/8	1/4
	400	1/125	1/60	1/30	1/15	1/8
f/32	50	1/8	1/4	1/2	1	
	100	1/15	1/8	1/4	1/2	1
	200	1/30	1/15	1/8	1/4	1/2
	400	1/60	1/30	1/15	1/8	1/4
f/50	100	1/8	1/4	1/2	1	
	200	1/15	1/8	1/4	1/2	1
	400	1/30	1/15	1/8	1/4	1/2
f/70	100	1/4	1/2	1		
	200	1/8	1/4	1/2	1	
	400	1/15	1/8	1/4	1/2	1
f/100	100	1/2	1			
	200	1/4	1/2	1		
	400	1/8	1/4	1/2	1	

Pressing the Shutter Button!

After everything else is said and done, what counts is what happens during the time the lunar image falls on the film. It doesn't matter if everything is steady up to the moment before you expose; if the image is shaking *during* the exposure, your picture will be blurry. One of the most common causes of shakiness at the moment of exposure occurs when the camera's reflex mirror lets go, and when there is some vibration from the shutter itself. In general, vibration won't bother you much if the exposure is 1/60 second or faster. If the exposure is longer — 1/4 second to a few full seconds — using a black card to block the eyepiece beam from the telescope, or a card or "hat" over the front end of the telescope, work well. In the middle range of 1/4 to 1/60 second exposures, the hand is not quick enough, and the reflex mirror can wreak havoc with sharpness. Many lunar photographers (and planet photographers also) swear by Laborec cameras which allow the reflex mirror to be swung up before releasing the shutter. Since the investment is considerable, make an honest effort with your present camera before buying another; yours may have a particularly easy release already!

Upper left: This full moon shot was made with a 12 inch f/6 reflector on a slow, fine grained film. Note the exquisite detail in the picture. Photograph by Lee Najman. Upper right: A first for the photographer, this picture was made using eyepiece projection with a 2.4 inch refractor on a clock driven mounting. Such fine results show lunar photography is not limited to bigger instruments. Photograph by Theodore Pollack. Lower left: Afocal lunar photography can mean freedom from shutter vibration because the camera doesn't need to be attached to the telescope. This picture was taken with a four inch refractor at 120 power; a 135mm lens was used on the camera for a 16,200mm effective focal length at f/162! The exposure was three seconds on GAF 500 film. Photograph by Danny Wright. Lower right: Afocal photography was used here with an eight inch f/5 Newtonian. The effective focal ratio was f/42, and the exposure 1/60 second on Tri-X film. Photograph by Bob Kimmel.

What kind of film should you use? Nearly any kind will do, though fast films reduce the tendency for vibrations to sneak in. Black and white films are more economical for something as colorless as the moon (especially if you do your own darkroom work), but, on the other hand, color slides are big and showy.

While fine lunar photography won't exactly force itself upon you without some effort on your part, you'll find that the moon isn't really very hard to photograph. With equipment you have now, you can begin lunar photography the next time you see the moon in the sky! ◆

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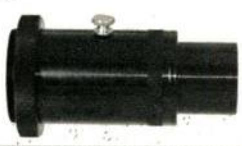

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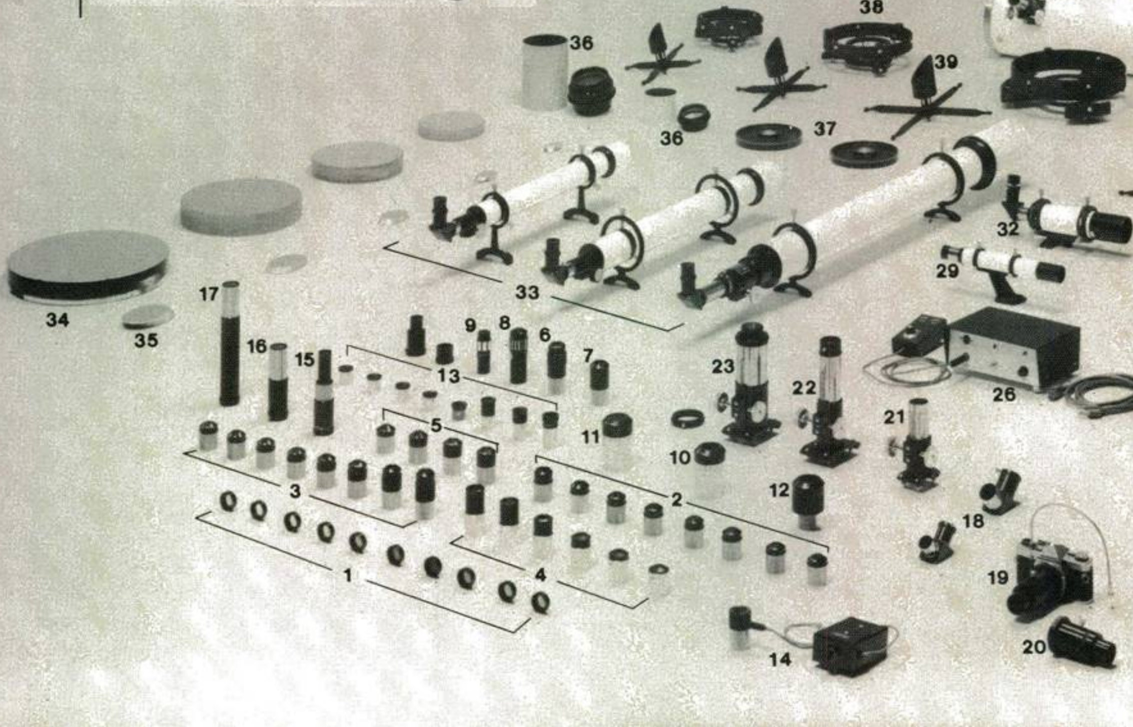

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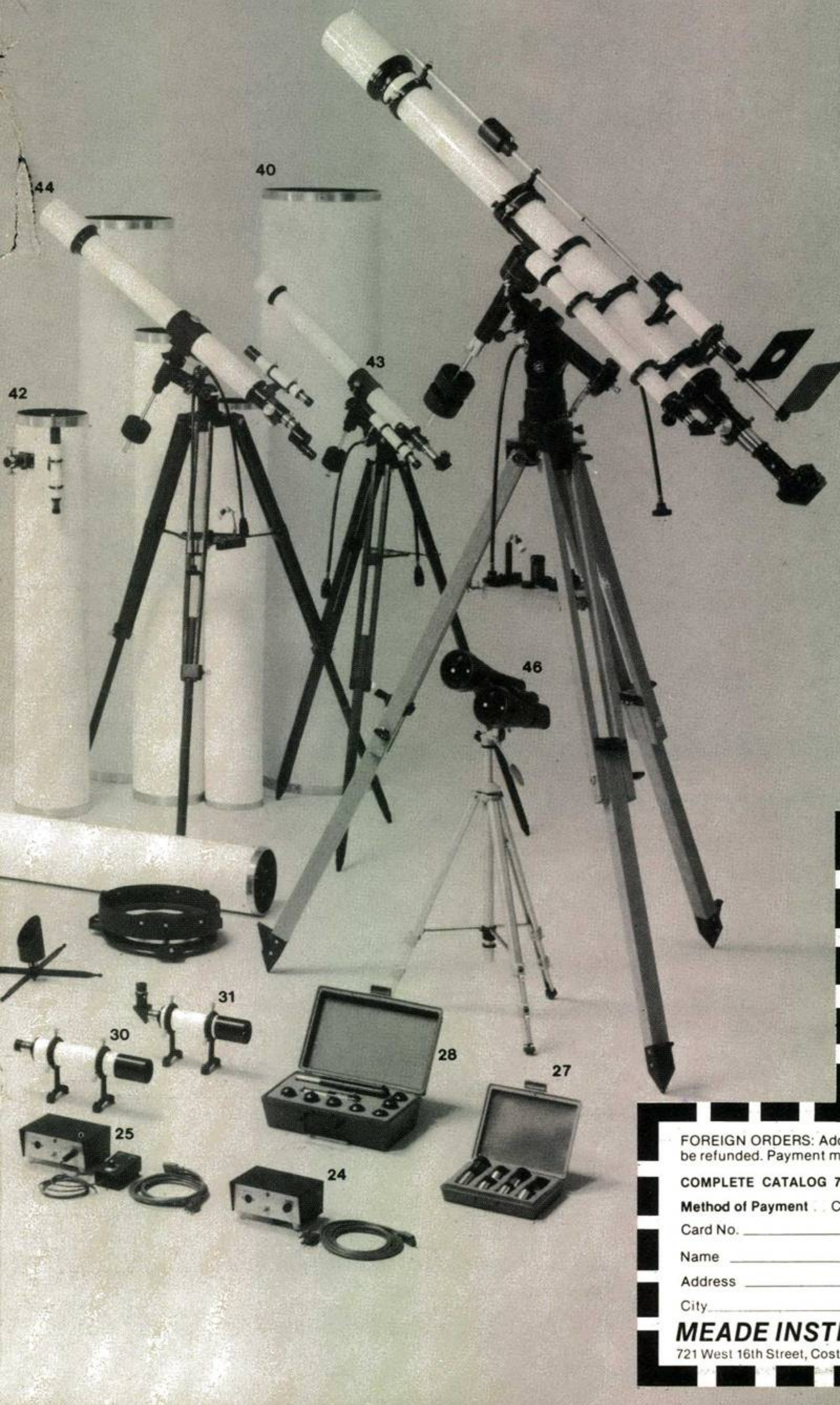

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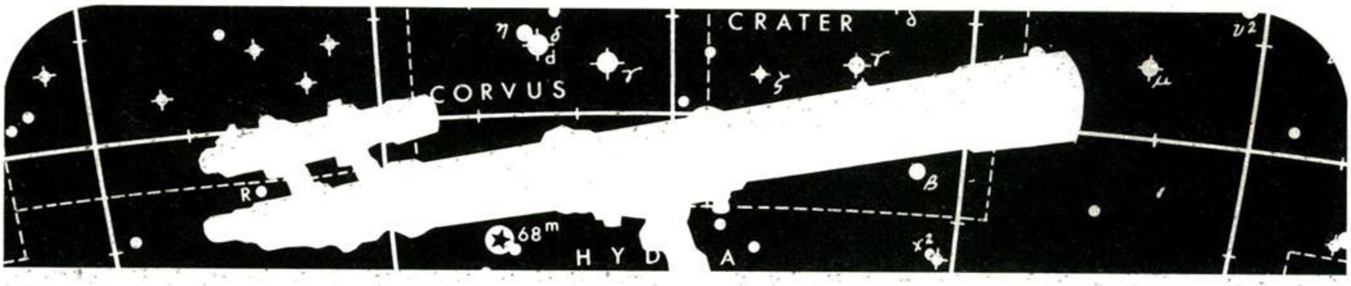


EQUIPMENT ATLAS

What You Can See Through A 6" Telescope

by

John G. Harmon

Perhaps you're contemplating the purchase of a six inch reflecting telescope — or better yet, you may already have one you've built yourself or received as a gift. In any case, you can hardly wait for the first clear night so you can peruse the wonders of the heavens.

When that night comes, assemble your scope and take it outdoors. If you happen to have an equatorial mount, find Polaris (using the "pointers" of the Big Dipper) and align the polar axis by pointing at this star. For most casual observing, this quick procedure will be quite adequate.

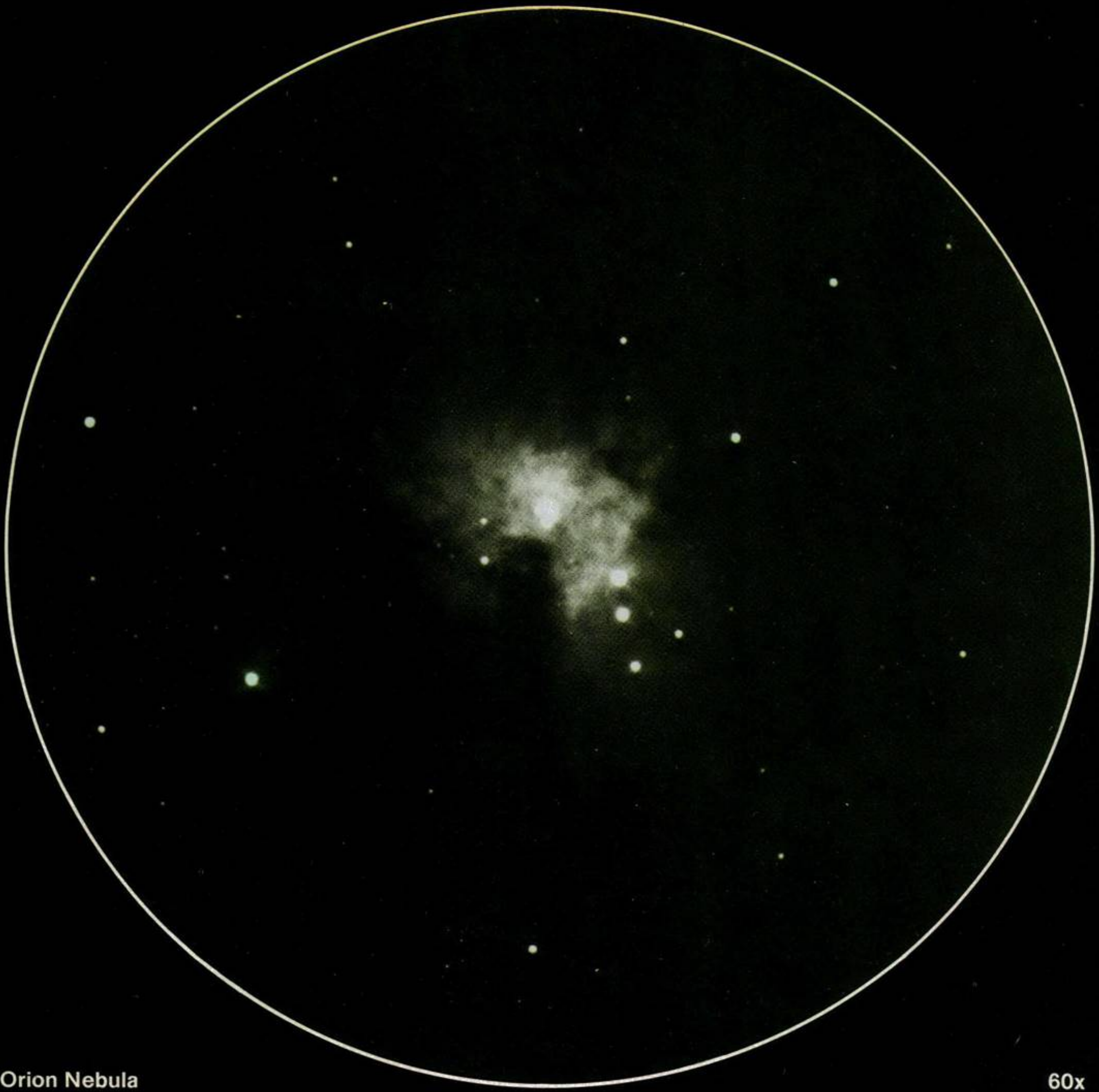
You'll want to choose a set of eyepieces that will give you a range of magnification from about 25 to 150 or 200 power. With a six inch telescope at powers lower than 25, not all the light gathered by the mirror can enter your eye. At the high end of the scale, while your six inch *could* permit magnifications as high as 300 power, under most conditions the extra power simply isn't useful because of less than ideal "seeing". Thus, 150 and sometimes 200 power seems a more reasonable compromise. A useful set of eyepieces would be a 28 or 30mm low power eyepiece, a 12 to 16mm medium power and a 6mm high power.

Now that you're ready, what do you want to look at first? The midwinter skies offer a wealth of objects, so it might be hard to decide where to begin. Perhaps it's best to start at the beginning: with our moon.

A six inch telescope can resolve features as small as 1-1/2 miles across. As the moon goes through its phases each night, new details become available for your inspection. As the terminator sweeps across the moon's surface, the interplay of light and shadow makes lunar features even more prominent. The best evening observing seems to be during the period from waxing crescent to just past first quarter. Three days after new moon, the Sea of Crises (Mare Crisium) with its mountainous walls comes into view. This mare appears to be oval, but it's actually circular in shape. The distortion is caused by its location near the moon's limb which presents a more side-on view. Two days later, the Seas of Fertility (Mare Fecundatis) and Nectar (Mare Nectaris) are both visible, as is the nearby crater Theophilus with its 18,000 foot walls and central peak. At first quarter, hundreds of craters — illuminated from the side — can be seen, as well as the Seas of Serenity (Mare Serenitatis) and Vapors (Mare Vaporum). Nine days after new moon, Tycho, with its central mountain and rays, and Clavius to the south — the moon's second largest crater — stand out. Farther north near the moon's equator, Copernicus with its magnificent system of rays and 17,000 foot walls appears isolated in the Ocean of Storms.

After getting a good look at our nearest neighbor in space, why not take in a few more distant members of the solar system. Three planets — Jupiter, Mars and Saturn — are visible tonight.

Jupiter is perhaps the easiest of the planets to observe. It was first viewed telescopically by Galileo in 1610. It's still interesting to repeat his observations and note the changing patterns that the four largest moons make as they orbit Jupiter (see this month's Sky Almanac). One of these moons, Io, takes only 1-3/4 days to complete an orbit, so it isn't uncommon to see it disappear behind Jupiter or pass in front of it casting a shadow on the cloud tops. With higher powers, the dark belts and bright zones can easily be examined. The bands are the result of atmospheric circulation and the planet's rapid rotation. The rotation, which gives Jupiter a 10 hour day, is most easily seen by watching the Great Red Spot. This oval patch was



Orion Nebula 60x

The Orion nebula, its central Trapezium stars twinkling wildly through the frigid winter air, is perhaps the single sight in the sky most beloved by telescope users — unless you'd award the prize to the cratered highlands of the moon, Saturn's rings, the sparkling beauty of the Double Cluster, Jupiter's Great Red Spot, the twinkle of the double star Mizar, or any of a hundred other celestial sights.

first seen by Robert Hooke in 1664, and is big enough to swallow several planets the size of Earth! Studies show it to be a huge storm — which varies in intensity from year to year — in Jupiter's atmosphere.

Mars, by contrast, is a *far* more difficult planet to observe. Atmospheric conditions on both Earth and Mars often obscure any detail, or play tricks on your eyes. There are, however, several features you can see under good conditions. Near the Martian equator, the dark markings of Syrtis Major and Sinus Meridani may be seen, or you may glimpse the polar caps. The southern cap is usually more prominent. During the Martian winter, it can extend to within 55 degrees of the equator, but then virtually disappear during the summer. Obvious to all observers, of course, is Mars' ruddy orangy color.

Of all the planets, though, Saturn is perhaps the most striking. Its system of rings extends about twice the diameter of the planetary disk itself. At the same time, the rings are so thin that the Voyager spacecraft could pass through them in a fraction of a second. There are several major sections to the rings. The outer two are separated by a 4,000 mile gap called Cassini's division. Inside these is a fainter Crepe ring which can be seen

40x
Great Nebula in Andromeda

Globular Cluster M-3
100x

40x
Double Cluster

under the very best conditions. Saturn, like all planets, is tilted on its axis, which affects the way we see the rings. Currently the rings are becoming more edge-on to Earth, and will continue to narrow between now and 1981, after which they'll open again. On the planet itself, bands like Jupiter's can be seen — and sometimes even the shadow of the rings can be glimpsed.

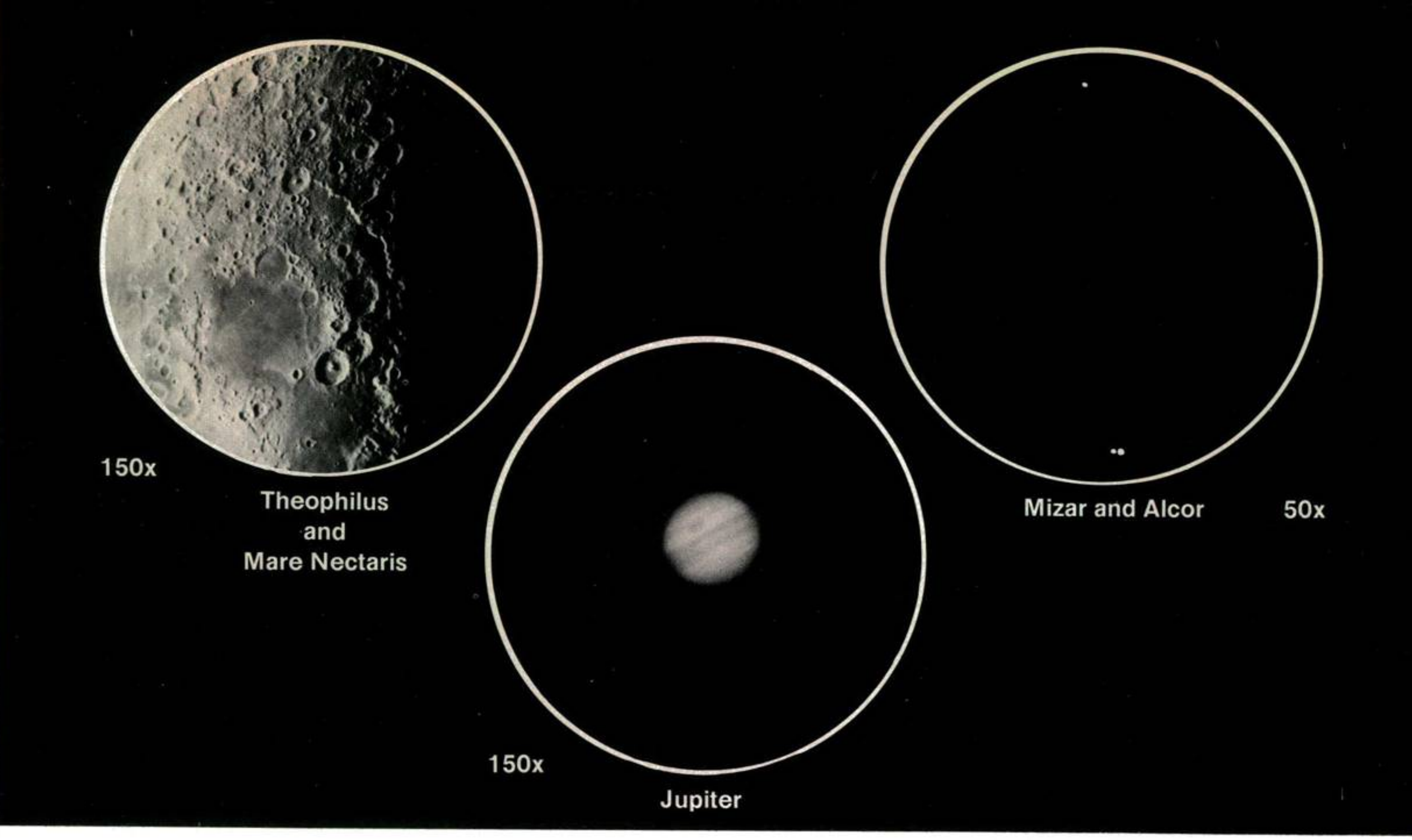
Like Jupiter, Saturn has a number of large moons including Titan, the largest in our solar system. Titan often appears as an eighth magnitude star about five ring diameters away from Saturn. Four other bright moons can also be seen in a six inch — Tethys, Dione, Rhea and Iapetus.

Moving from the wandering to the fixed stars, we find that a number of them which appear as single stars to the naked eye are in fact composed of two or more stars together. One of the most famous of these is Mizar in the handle of the Big Dipper. It forms an optical double with its faint companion, Alcor. Examining this star in your telescope, however, you'll find that it appears as two stars close together with Alcor off to the side. Gamma Leonis in the "sickle" of Leo is another pair of easily separated stars, while the bright star Castor in Gemini is something of a challenge. Sometimes each of the components of a double star is a different color. Gamma Andromeda, the brighter of the pair of stars at the open end of this V-shaped constellation, is made up of stars that appear to be colored blue and yellow. Sigma Orionis offers contrasting colors also, as well as the bonus of four stars being visible instead of only two. This multiple star system is found just below the most southerly of Orion's belt stars. (Each month you'll find new pairs described in Star Dome's Close-Up section.)

Another interesting sight is the clusters of stars where you'll see not just two or four, but hundreds or even thousands of stars. Many of these objects were found by the French astronomer Charles Messier, who catalogued them as an aid in his comet hunting. Messier 35, 36, 37 and 38 are four beautiful examples of the type of cluster known as open (sometimes called galactic). All four are found along the winter Milky Way. M-35 lies near the feet of Gemini and close to the tips of Taurus' horns. About 20 stars are easily seen, and some observers can spot over 100. The next three are all in Auriga, in the rich area between Theta Aurigae and Beta Tauri. M-37 is perhaps the best and has been called one of the finest in its class.

Number three in Messier's catalog (M-3) is an example of a globular star cluster — a type that is more distant and contains more stars. It is found in Canes Venatici, a constellation of faint stars between the handle of the Big Dipper and Denebola in Leo. M-3 is estimated to contain 250,000 stars. In its outer regions, a six inch scope can separate hundreds of separate stars.

The February sky also contains one of the brightest nebulae in the sky. Below the "belt" of Orion hang the stars of his sword. Examination with binoculars will reveal that the "star" in the middle is not a star at all, but a group of four stars, the Trapezium, with a good deal of milky haze around them. What you are seeing is the Great Orion nebula, or M-42.


150x
Theophilus and Mare Nectaris

150x
Jupiter

Mizar and Alcor 50x

Up to now, the objects you've observed will have looked pretty much like their pictures taken through large telescopes. With the Orion nebula, however, this is not the case. Pictures usually show a large, bright cloud of gas that is distinctly red in color. The sad fact is that much of the gas and its reddish hue is much too faint for the eye to perceive — even when aided by a powerful telescope. An interesting note, though: If your eye could see all of M-42, it would appear as large as the full moon. After examining M-42 at low power, use your highest power to zero in the innermost region around the Trapezium.

Another nebula, and the first object to be catalogued by Messier, is the Crab in Taurus. M-1 is located near the tip of the southern horn of the bull, which is marked by the star Zeta. To find this object, you'll need a crystal clear, moonless night, as well as some degree of patience. Those who succeed in the attempt will be rewarded with viewing the remains of the supernova of 1054 A.D. Back then, it was much easier to see: This exploding star was 100 million times brighter than our sun and was visible even in daylight!

So far all the things you've looked at have been within our own Milky Way galaxy. There are, however, a number of other galaxies within easy reach of a six inch telescope. Perhaps the most prominent of these is M-31, often called the Great Nebula in Andromeda. This name belies the early idea that this — and other similar nebulae — were part of our own galaxy. The Great Nebula is, in fact, the largest and most distant object visible to the unaided eye. It is a galaxy of about 200,000 stars located about 2-1/2 million light-years from our own Milky Way. Unfortunately, like the Orion nebula, M-31 appears best in photographs. Visually, it's best at low powers since it extends over five times the diameter of the moon along its long axis. Its appearance is that of a milky oval, brightest in the center. It was described by its first telescopic observer, Simon Marius, as resembling "the diluted light from the flame of a candle seen through horn".

A pair of galaxies can be found in Ursa Major. These are known as M-81 and M-82, and at low power, both can be seen in the same field of view. They are part of a cluster of galaxies that is about 8-1/2 million light-years away. To find them, locate the Big Dipper. Draw a diagonal line across the bowl from the star Gamma to Alpha. Extend that line about its own length in front of the Dipper, and it will point right at the galaxies. M-81 is the larger, more oval shaped of the two, since it is seen nearly face-on. M-82 is seen edge-on and looks like a hazy dash in the sky.

This is only a beginning list of the fascinating objects that you can see with a six inch telescope. Any one of a number of good star atlases and observer's guides exist to enable you to find those we haven't mentioned here. Each month Gazer's Gazette and Close-Up also bring you more hints on what to see. So get out there on clear nights and see how many of these wonders of the skies you can find as you look out into space!

Photo credits: Theophilus, Jean Dragesco; M-3, Leo Henzl; Jupiter, Don Machholz; Andromeda nebula, Hal Jandorf; Mizar and Alcor, E. Schirmer; Double Cluster, Robert Provin; Orion nebula, Richard Berry.

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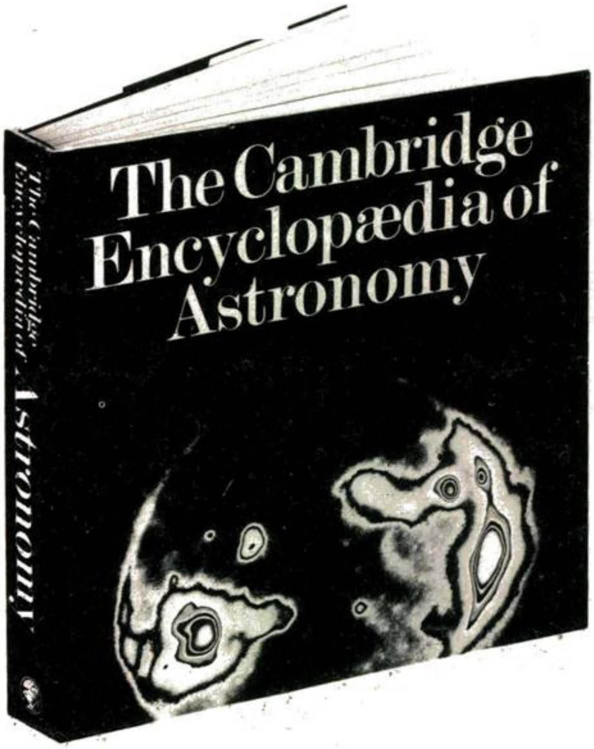
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GAZER'S GAZETTE

Observing Venus

by

Frank Apsi

A new season of Venus observing will begin this month as the brightest planet gradually creeps from the sun's glare into visibility in the evening sky. From February through late October this year, Venus will provide one of the sky's most dazzling displays as it swings around in its orbit from one side of the sun to the other.

At its brightest, Venus is a marvelous pearl of light that shines at magnitude -4.4 — brighter than all the visible stars and other planets. In fact, Venus is the third brightest object in the sky; only our sun and moon shine with greater brilliance.

Because it will be visible during the early evening during the spring and summer months, Venus will be noticed by many more of you than when it appeared in the morning sky (from April through December last year). Observatories and planetariums are frequently besieged with calls from startled people who want to report the unusual sight they've just seen in the sky; most of the callers, unaware of just how bright a planet can be, claim they've never seen such a brilliant "star" before.

If Venus could be seen during the middle of the night, the number of calls would undoubtedly be diminished, because we naturally associate bright "stars" with nighttime. But since Venus is seen most of the time against a background of blue twilight, neophyte skywatchers are confused. How can something shine so brilliantly when the sky hasn't even turned completely dark? Even from light polluted urban areas, Venus puts on quite a show in the evening.

Why can't we see Venus in the middle of the night? The answer, with seeming irrelevance, lies in Venus' position in the solar system: It is an *inferior planet* (its orbit lies inside Earth's, so that it's closer to the sun than Earth is). The result is that Venus is never on the opposite side of Earth from the sun, and so is never high in the sky at midnight, the way the outer planets are.

Instead, the best time to see Venus is when it is at the point in its orbit called *quadrature* — when the sun-Venus-Earth angle is exactly 90 degrees. When Venus reaches one of these points, we say that it's at *greatest elongation*, because the planet is at its maximum distance from the sun as seen from Earth. When Venus is west of the sun and in the evening sky (as it is during most of this year), it's at greatest western elongation.

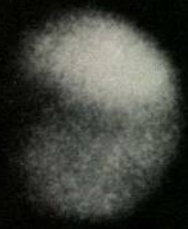
To avoid confusion, remember that these directional notations refer to Venus' position relative to the sun — *not* to the part of the sky it's in. When Venus is at greatest *eastern* elongation, we see it in the *western* sky.

Two other orbital positions of Venus must also be mentioned. When Venus is directly between Earth and the sun, it's in *inferior conjunction*; when it lies on the opposite side of the sun from Earth, it's in *superior conjunction*. Venus is now emerging from the latter; it will reach greatest eastern elongation this year on Aug. 29, and will be in inferior conjunction on Nov. 7.

As seen from Earth, Venus never departs from the sun by more than 47 degrees of arc — about 1/4 the distance from the horizon to the meridian. This means that it rises or sets a maximum of about 3-1/2 to 4 hours before or after the sun. You can see

Venus exhibits phases much like the moon does. The "full" phase occurs at superior conjunction when the planet is on the other side of the sun. As the planet approaches inferior conjunction (when it is between us and the sun), the disk grows larger while the phase grows smaller. This sequence of ultraviolet photographs taken in 1967 shows Venus shortly after superior conjunction as it approaches inferior conjunction. Lunary and Planetary Laboratory photograph.

The Changing Faces of Venus



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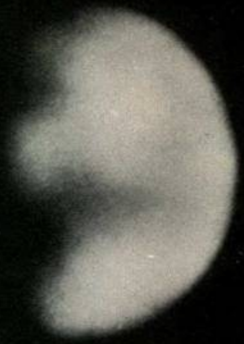

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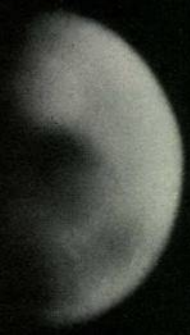

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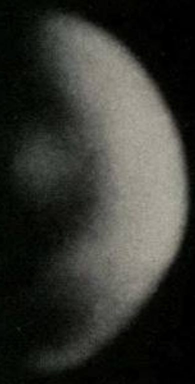

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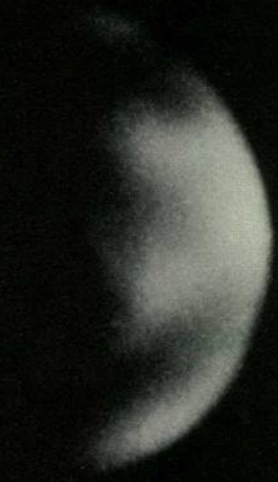

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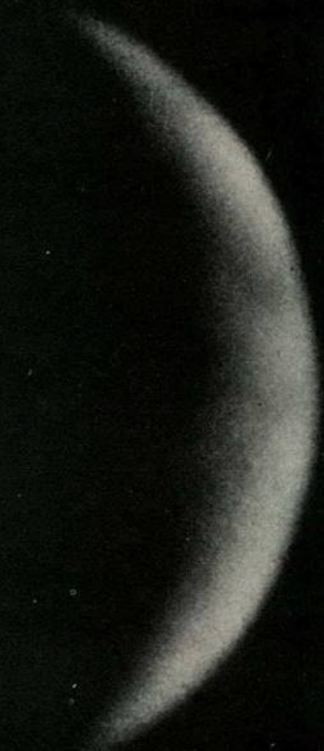


July 26

Venus in a completely dark sky, but at such times it's close to the horizon, not high overhead.

Venus' position as an inferior planet allows us to view it lighted at various angles. Venus exhibits phases much like our moon's; these phases are by far the most obvious telescopic feature of the planet. The planet is "full" when it's in superior conjunction, but of course it's hidden by the sun at that time. As it swings toward inferior conjunction, approaching Earth, Venus' disk grows larger and larger while its phase grows progressively smaller. Near inferior conjunction, Venus' apparent diameter can measure up to 64 seconds of arc (about 50 percent larger than the disk of Jupiter) — but at the same time it's an extremely thin, narrow crescent.

We're therefore treated to an ever-changing view of this planet. The outer planets change in size as they move nearer or farther from Earth, but they don't exhibit phases; the moon shows phases, but doesn't noticeably change size. Venus combines the two phenomena, and its constantly shifting appearance is a source of endless fascination.

Even a 2.4 inch (60mm) refractor will present a large, exquisite view of Venus, with the phase readily distinguishable. Larger apertures will help when the planet is near one of its conjunctions and near the horizon. In any telescope, Venus is a superb sight and a real showpiece. You'll look in vain, however, for any obvious detail (aside from the phase) on its disk. Why is this?

The surface of Venus is completely blanketed by a dense, impenetrable cloud layer that prevents us from seeing any true surface features. The clouds are extremely efficient reflectors of light; the *albedo* (reflectivity) of Venus is 76 percent — the largest value of any of the planets. Venus is actually bright enough to be seen in broad daylight, any time of the day, if you know exactly where to look. The clouds usually appear white and featureless, but a faint lemon-yellow coloration can sometimes be detected in a six inch telescope.

Early astronomers, particularly those who lived during the 18th century, imagined they saw surface features through occasional gaps in the clouds. Some even produced detailed maps that showed the planet covered with oceans, continents and extensive mountain ranges. While such features were certainly the artifacts of these astronomers' imaginations, Venus does have delicate pale shadings called *dusky markings*, that can occasionally be glimpsed on its sunlit clouddeck.

Dusky markings appear in many different forms and shapes: large irregular diffused areas, elongated streaks, bands or a series of parallel bands located mainly near the equatorial region, or groupings of patches that seem to have a radial or "spoked wheel" pattern. These shadowlike features are undoubtedly related to the structure of the upper cloud layers on Venus. As a rule, you'll need a four inch or larger telescope to see them — although owners of 2.4 inch scopes have reported detecting the markings.

If you think you might be seeing the dusky markings when you gaze at Venus through your telescope, you can greatly enhance them by placing an appropriate filter before the eyepiece. Filters with a spectral transmission range between 3,800 and 5,000 Ångstroms work well in this capacity; typical of the type employed are Wratten #47 (violet) and #W80A (blue) filters.

Since the dusky features are always difficult to discern because of their low contrast, there is an ever-present danger of subjective illusions being mistaken for them. French astronomer Audouin Dollfus (from Meudon Observatory) has made an extensive visual study of Venus and found that visual illusions can be essentially eliminated simply by using high magnification. According to Dollfus, powers of 300 or more will remove illusionary effects and permit study of the dusky markings.

In addition to the dusky features, Venus has been known to display bright circular ovals and spots. These infrequent markings tend to have a yellow hue to them, but they're difficult to detect. Usually a larger aperture — six inches or more — is required. Terminator shadings can also sometimes be seen. Such a shading consists of a duskiness that extends completely along the length of the illuminated edge of the terminator.

The "cusps" or tips of Venus' crescent have also been observed to undergo curious changes. These normally sharp pointed features often appear to be blunted or "sawed off". In addition, differences in the size and appearance between the northern and southern cusps have been reported. When present, this effect gives the planet a somewhat asymmetrical aspect.

Near the times of inferior conjunction, Venus has a particularly pleasing appearance; it becomes an extremely slender crescent whose cusps extend deep into the nighttime side of the planet. These "cusp extensions" continue completely around the limb of the disk forming a marvelous ring of light. The cusp extensions result from scattering and refraction of sunlight by the atmosphere on the sunlit side of Venus. In effect, the cusp extensions indicate the extent of the atmosphere on this remarkable planet.

From time to time observers have reported detecting a pale illumination covering the entire dark section of Venus' disk. This lighting, called the *ashen light*, resembles the Earthshine that illuminates the dark portion of our moon during its cres-

Top: Venus flashes a display of brilliance before dipping below the trees. Saturn is visible to the left of Venus, with Castor and Pollux (in the constellation Gemini) in the upper left portion of the photograph. This photo was taken using a 35mm camera with a 50mm lens on a tripod with GAF 500 film exposed for 20 seconds at f/1.4. Photograph by Diane Payton. Bottom: Venus and the Pleiades make a pretty picture in this 20 second exposure on Fujichrome 100 film. A 35mm camera was used with a 58mm lens at f/1.4. Photograph by Dennis Stayer.

cent phases. Earthshine results from reflection of sunlight off Earth that intercepts the moon's surface; what we see is sunlight "twice reflected". But Venus has no object (like a large moon) nearby to serve as a convenient light reflector.

Back in a more romantic astronomical era, when Martian canals were thought to transport scarce water from the poles to the dry equatorial regions of Mars, some astronomers attributed the ashen light to illumination from great cities and industrial areas which dotted the surface of Venus. Others, taking a somewhat more conservative approach, theorized that the glow was from huge lightning discharges occurring deep within the dense atmosphere of the planet.

Recent studies of the phenomenon by a group of planetary scientists have disclosed that the ashen light is probably the result of the recombination of oxygen molecules in Venus' upper atmosphere. This process produces, as a byproduct, a pale illumination, similar to the very faint nighttime airglow present in Earth's atmosphere.

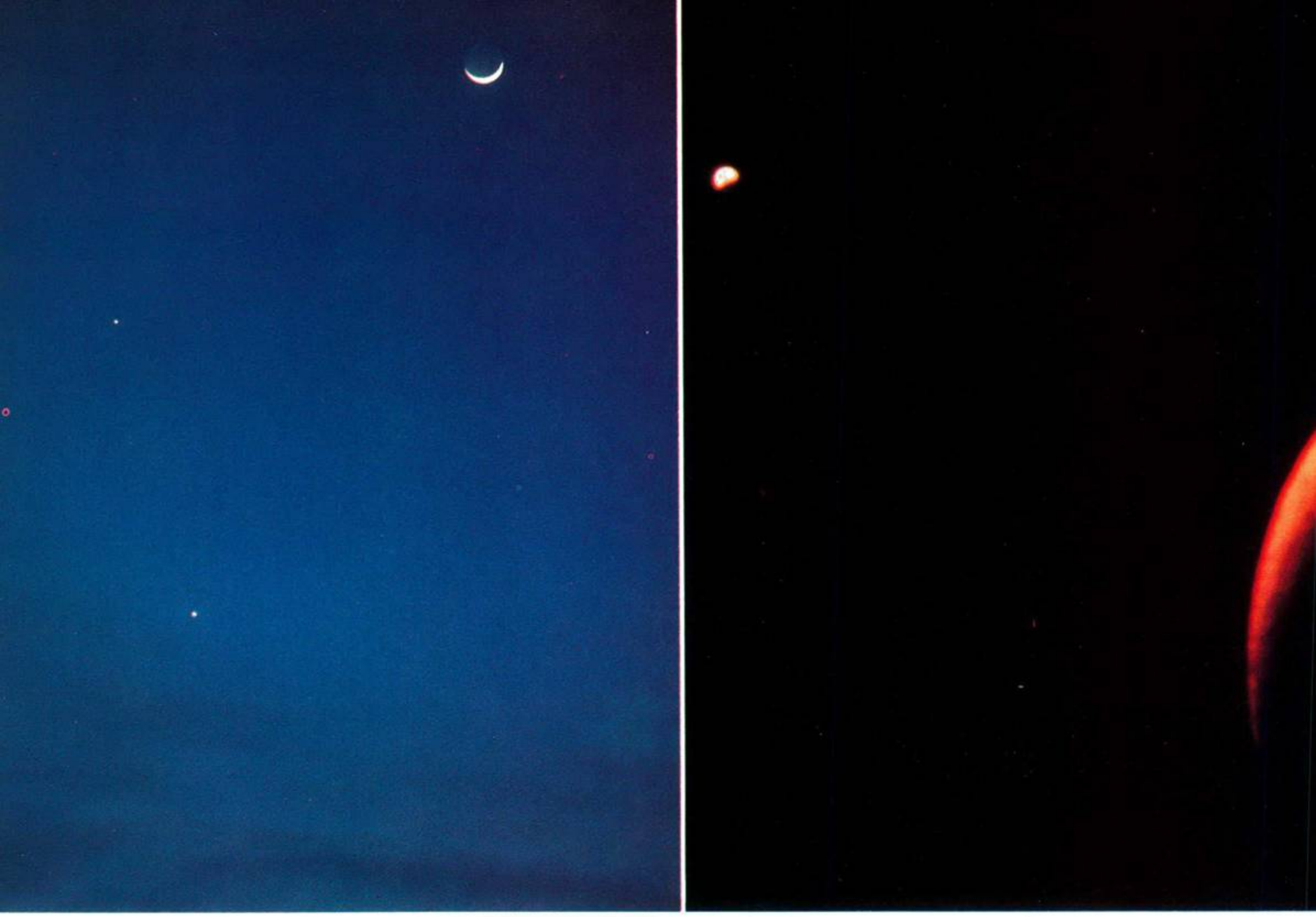
The ashen light is difficult to detect because it is a low light level phenomenon that is situated immediately next to the extremely brilliant sunlit portion of Venus. The large difference in contrast can completely wash out the faint glow of this dark hemisphere illumination. To reduce this "washout effect", you can insert an occulting mask, fashioned in a crescent shape, within the eyepiece.

Left: Venus is actually brilliant enough to be seen in the daytime, as shown here. A 35mm camera with a 2x Barlow adaptor and an eight inch Schmidt-Cassegrain were set up for Cassegrain focus. Kodachrome 25 film was exposed for 1/30 second and printed on Cibachrome direct-positive color print material. Photograph by Clayton Ruth. Right: Venus displays its brilliance most effectively at night. A 12mm projection method was used with an eight inch Schmidt Cassegrain at f/11.7. The exposure was for 1/2 second on High Speed Ektachrome film. Photograph by Steve Reed.

An occulting mask is simple to construct — all you need is a piece of black construction paper and a pair of scissors. First, cut out a circular disk from the construction paper that will fit the inside diameter of your eyepiece. Then cut out a semicircle from the disk, adjusting the curvature to approximate the crescent of Venus as seen through the telescope. (You'll need to know what phase Venus is in before cutting the semicircle. Either check it through the telescope or look up the information in a reference book.) Next, insert the mask within the eyepiece and adjust its position, by sliding it back and forth, until it appears in sharp focus.

Once you've properly adjusted the mask, simply block Venus' crescent from view behind it so you're viewing only the unlit part of the planet. The ashen light will be much more conspicuous when it is present.

Yet another peculiar dark hemisphere phenomenon that has been reported by observers is the appearance of two strange, bright patches of



Left: The three brightest objects in the sky make up this particular grouping: the moon, Jupiter and Venus (pictured in descending order). A 35mm camera with a 135mm lens at f/4 was used to make this four second exposure on High Speed Ektachrome pushed to ASA 400. Photograph by M. Flood. Right: Venus is seen approaching the moon prior to occultation. Here the planet exhibits a phase similar to the moon's phase two days before first quarter, and is shown 0.3 degrees from the moon. The photograph was taken using a 4-1/2 inch reflector. Photograph by Richard Andreassen.

light near the cusps. These brightenings assume various forms and are often located at a considerable distance from the true cusps. Astronomers call these patches the "cusp caps" of Venus; their nature is not yet understood.

Owners of all sizes of small telescopes have detected the cusp caps, but they are best seen through larger apertures. A yellow filter seems to enhance their appearance at times.

Because Venus' disk is so bright, its telescopic image is usually surrounded by an annoying glare. You can greatly reduce this glare by observing Venus during twilight, when there isn't as much contrast between Venus and the sky background. Another glare reduction technique that works well is simply to use high magnification — about 40 to 50 power for each inch of aperture.

If you use a star diagonal on your telescope, you can replace it with a glare reducing device called a *Herschel wedge*. This implement looks just like a star diagonal but has a clear glass element in place of the usual reflecting mirror. Since the Herschel wedge transmits to the eyepiece only about 10 percent of the light it receives, glare is cut down considerably. Obviously, you shouldn't use a Herschel wedge while searching for the faint dusky features or the ashen light — only when you're enjoying the sight of Venus' disk for its own sake.

If you like photographing the planets, Venus is an excellent subject — especially during the periods around inferior conjunction, when Venus attains an angular diameter greater than any of the other planets. Also, because Venus goes through phases, you can obtain a particularly interesting series of photos by following the planet as it moves from superior to inferior conjunction. Photograph Venus once every two weeks or so — more often as the planet nears inferior conjunction — and you'll have an excellent series depicting an ever changing disk, growing in size and varying in phase.

You may occasionally hear Venus described as a white, featureless disk that's scarcely worth the effort to view. In fact, just the opposite is true. Venus offers a wealth of fascinating, challenging detail — much of it still unexplained. Give Venus a try during the new observing season. With a little patience and practice, you'll soon recognize that Venus, like every other planet, has unique attractions that will draw you to the eyepiece again and again.

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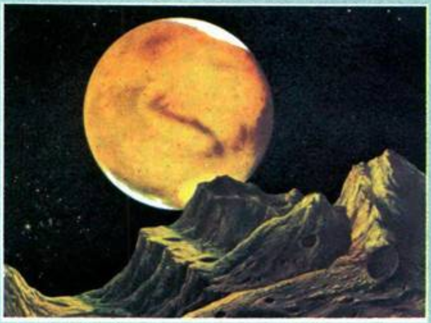

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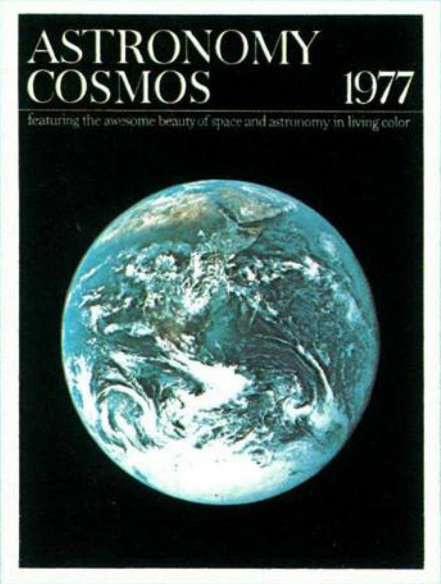
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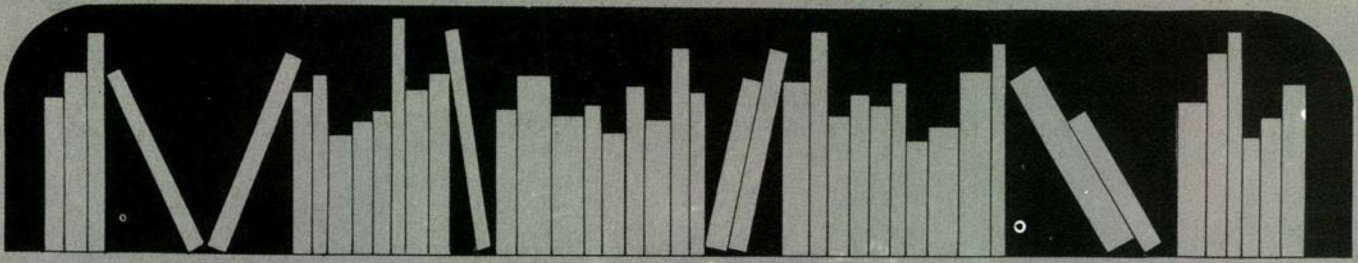

U.S. - Soviet Cooperation in Space

by DODD L. HARVEY and LINDA C. CICCORITTI

408 pages, hardcover, $8.95*
University of Miami (1974)

Now that American and Soviet spacemen have shaken hands in space, observers are justified in asking what comes next. Although valuable in itself, the Apollo/Soyuz Test Project (ASTP) was prominently portrayed as "only the beginning" of expanded space cooperation.

In understanding and predicting the future, an analyst always needs to understand the past. This exhaustive collection of source documents and memoirs about previous attempts to cooperate in space with the Soviet Union is a valuable tool in understanding the events and trends which led to ASTP.

Throughout the first 1-1/2 decades of the space age, many commentators continually decried the wastefulness of the space race. These critics charged that nationalistic circles in Washington and Moscow were deliberately blocking any possibilities of true space cooperation.

But the hundreds of pages of documents and quotations put together by historians of the "Center for Advanced International Studies" in Miami reveal a different picture: They show attempt after attempt by the United States to interest the Soviets in a wide range of initiatives on an entire spectrum of cooperative space projects, with very little response. As former U.S. ambassador to Moscow Foy Kohler perceptively points out in the forward to the book, ". . . space cooperation with the Soviets depends less on U.S. initiatives, however dramatic or ingenious these might be, than on cold calculations on the part of the Soviet authorities themselves." And it was not in Moscow's interest to lift the heavy veil of secrecy from its space program — a veil which has fallen back into place with a resounding thud following the end of the ASTP flight.

The reasons for this Soviet secrecy are examined. They deal with fear of foreigners, reluctance to admit to space failures (while almost jubilantly reporting all U.S. failures in the Soviet press), and a desire to utilize space headlines for political and ideological purposes back on Earth. This is not a pretty picture, but the evidence is here. A casual reader may feel crushed by the evidence; however, this is a sourcebook, not an ordinary explanatory work. It can be quite overwhelming at times and whole pages can be skipped in the reading without anything being missed.

What about the future? Harvey and Ciccoritti do not paint a very optimistic picture of a space program devoted to military, propaganda and occasionally scientific ends. One particularly large factor is "... the magnitude and strength of the barrier which the relationship of Soviet space activities with the Soviet military establishment interposes to effective cooperation between the U.S. and the USSR".

Other countries have responded to American proposals, and a truly international space program is the result. The Europeans and Canadians are helping build the Space Shuttle system; space crews from Italy, France, Sweden, Holland, Spain, England, Indonesia and many other nations cooperate with the U.S. Moscow has had the same or even greater chances to respond, but with little results. They have not even taken the simple step of advising Western scientists in advance about Soviet space plans, fearing failures might be revealed. (This is a legitimate fear; when Russia finally tried to launch a satellite for Sweden, the booster rocket exploded and the Swedes had to be told.)

Since the publication of this book, there have been further cooperative space activities. A Soviet "Kosmos" biosatellite carried American specimens into space for a few weeks. The Soviets have launched a satellite for India. But they still have not lifted their main barrier to true scientific cooperation — their almost paranoid fear of losing their protective shroud of mystery and secrecy, which hides their weaknesses and allows them to exploit space exploration for less noble goals. "All things considered," the authors conclude, "it is unlikely that the present enterprises — whatever their degree of success — will serve as stepping stones to broadgauged space cooperation between the two countries, much less to any interlocking of the space programs."

This book is a useful counterpoint to various optimistic visions of future relations with the USSR. The Russians have already officially labeled the work "an attempt to revive the Cold War." Any reader interested in spaceflight in the context of world politics will find the volume very useful, even if the Russians would rather you would not read it. Their success in rewriting their own version of the space programs of both countries is well documented in the book; they do not have the power to rewrite this powerful documentary. *James E. Oberg.*

**Available from Center for Advanced International Studies, Suite 1213, 1730 Rhode Island Ave. N.W., Washington, D.C. 20036.*

U. S. Observatories: A Directory and Travel Guide

by H. T. KIRBY-SMITH

173 pages, paperback, $6.95*
Van Nostrand Reinhold Company (1976)

Unhappily, astronomers can't reach the objects they observe. But there are other kinds of astronomical tourist attractions: observatories and planetariums around the country (and nearby campgrounds) which travelers and students can visit. This book is a travel guide to these institutions.

Kirby-Smith's writing style and knowledge of astronomical instrumentation are both more than suitable to this novel compilation of observatories. The volume includes historical surveys, descriptions of available equipment, active observing programs, many unique and original anecdotes and educational resources.

In addition to touring and camping applications, Kirby-Smith hopes that teachers can use the catalog to plan field trips. The book will also provide genuine entertainment and pleasurable education for armchair travelers.

After being unable to contact the "Mummy Mountain Observatory" (the Postal Service returned the envelope marked "deceased"), Kirby-Smith combed a number of lists of installations in an attempt to cover all facilities of possible interest — and there do not seem to be any significant omissions. (The author asks for advice from readers for a hoped for and well deserved second edition, but fails to provide an address.)

An example of the style and substance of Kirby-Smith's commentary is his description of the Harvard-Smithsonian Joint Center for Astrophysics in Cambridge: "The two names belong together, certainly. To the extent that they have been connected with astronomy, they have meant flexibility, enterprise, international connections, an appreciation for the public interest in astronomy, a certain amount of crankiness, an indulgence toward amateurs, initiative in undertaking projects of doubtful outcome, appreciation of the personal history of scientists and the peculiar histories of scientific institutions, sophisticated naivete, hospitality toward women scientists, and a genius for organization. In reading book-length histories of both institutions and in studying their current undertakings, one becomes aware that they display simultaneously the virtues of youth and old age, without the vices of either."

Such information and insight is not readily available elsewhere. That is one of the pleasures and uses of this book. Whether for a would-be visitor or a devotee of astronomical gossip, Kirby-Smith has performed a valuable service. *James E. Oberg.*

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Scientific Uses of the Space Shuttle

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Criticisms of the Space Shuttle program have begun increasing as it nears completion. Congressmen and columnists have accused it of soaking up the whole NASA budget (it actually gets about 1/3) and of being "a ferryboat to nowhere." It has been accused of being "an aerospace industry boondoggle," "space makework," and worse.

But the economics of the program are authentic. It will launch dozens of application satellites in various communications, navigation and military programs, and will be cheaper and more reliable than present systems. It will advance the state of the art in rocket engines, aerodynamics, materials and computers, and will also contribute to science — particularly astronomy.

That last contribution is the subject of this special report by the National Academy of Sciences, which details all the possible areas of scientific research which the Space Shuttle will open. As such, the report announces the opportunities soon to become available to scientists. It also advertises the true scientific value of the rocket plane, contradicting certain common charges.

The primary scientific configuration of the Space Shuttle is the "sortie mode", carrying a special laboratory module called "Spacelab", and a crew of two pilots and up to five scientists. The Spacelab (built by the European Space Agency) can consist of a pressurized module, a long "pallet" loaded with instruments, or an even combination of the two.

This booklet describes seven major fields of investigation to be carried out from the spacelab systems: atmospheric and space physics, high energy astrophysics, infrared astronomy, optical and ultraviolet astronomy, solar physics, planetary exploration by remote sensing, and life sciences. Six of these seven are of direct interest to astronomy enthusiasts, and life sciences must also be studied [including, after all, the science of keeping astronomers (and other humans) alive in space to do their research]. It may also find the key to a cure for cancer!

One hundred scientists in the Academy of Sciences study group formulated 10 major conclusions. Among the most important are those asserting that:

— the shuttle can be an important asset to scientific research in and beyond the 1980s.

— many of the potential advantages of the shuttle depend on the development of efficient and flexible procedures for flying multipurpose missions and combined payloads.

— many disciplines require rapid interaction between man and payload, thus meaning both good communications and many scientists in space.

These are clearly requirements for further definitions and development of payload programs. Scientists should insist on them; without them, some of the criticisms of the project may come true by default.

Each of the specialized chapters describes one major field of research by outlining scientific objectives, candidate instruments, the role of the scientist-astronaut in flight, mission models, and a summary and recommendations section. Tables of "payload requirements" list the scientific instrumentation and characteristics such as crew interface, pointing and stabilization, orbital parameters, weight-size-power, types of detectors, data storage and processing, and ground control requirements. It is an instruction book on "how to build a space science mission."

For example, the optical and ultraviolet astronomy chapter discusses problems to be investigated in the solar system (planetary atmospheres imaging), stars and stellar systems (ultraviolet star classification criteria), interstellar matter (light extinction in the UV), emission nebulosities (abundance determination), galactic nuclei and quasars (redshifts of faint objects), intergalactic matter, extragalactic research and cosmology. Specifications are given for such equipment as the Space Telescope, a diffraction-limited telescope, a small general-purpose telescope, a very-wide-field survey camera, and a very large light collector.

The book is a reference guide to possibilities, not a prediction. It is a condensation of an extensive study and does not make for easy armchair reading. As a guidebook to the backgrounds of actual space science projects now being considered, it is invaluable. The exciting contents are still only potential benefits; reading about them and acting upon the proposals can help make it all a reality. The Space Shuttle could become the greatest boon to astronomy since the telescope, and this book tells how it could happen. *James E. Oberg.*

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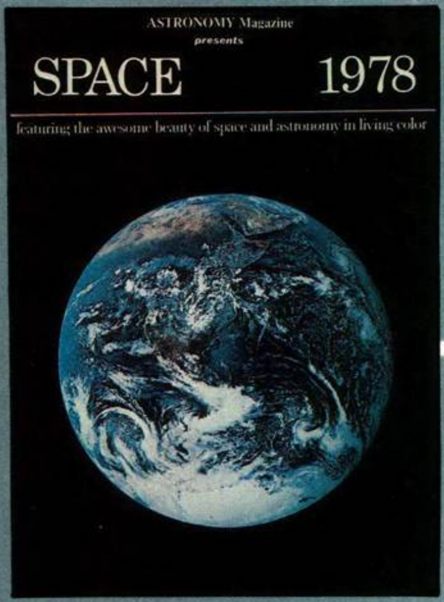
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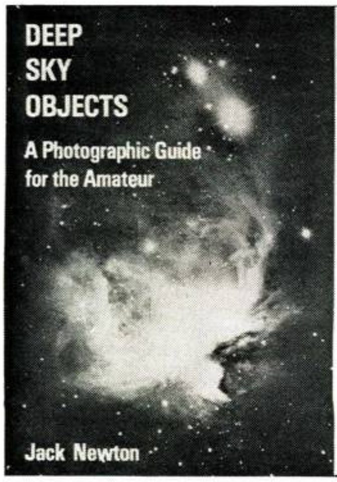

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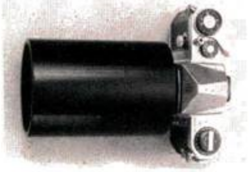

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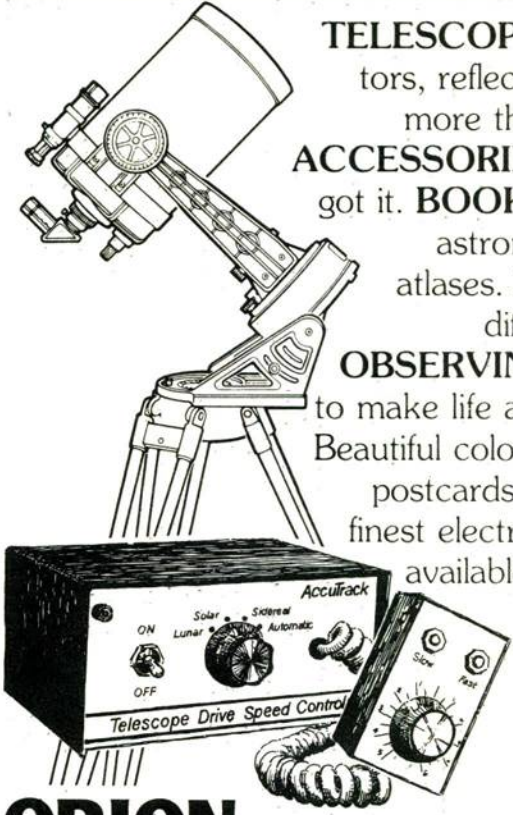

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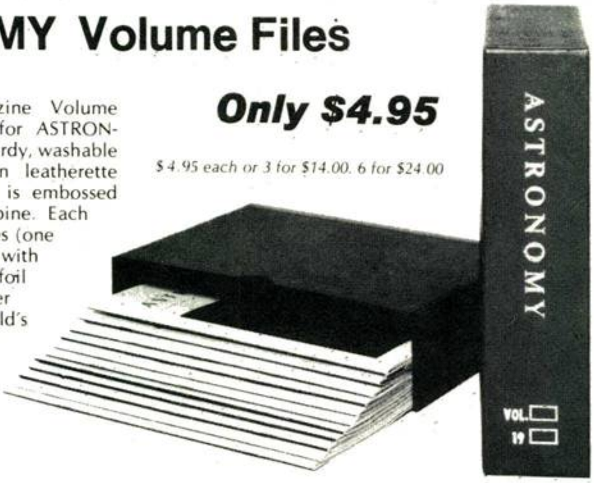

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ASTRO-NEWS

Latest News From the World of Astronomy

Kowal Discovers Miniplanet

On Nov. 1, 1977, astronomer Charles Kowal of the Hale Observatories was examining some photographic plates to see if they revealed any faint comets. What Kowal found on those plates wasn't a faint comet, but a "miniplanet" — a cross between a planet and an asteroid.

Kowal had used the 48 inch Schmidt telescope at Palomar Observatory on Oct. 18 and 19 as part of a systematic survey he is doing on the solar system. He had put the two plates on a *blink microscope* — a device in which rapidly alternating views of the same portion of one plate and then the other can be seen through the eyepiece. The stars in the background remained pinpoints, but there was something making a blur. Tom Gehrels, a visiting astronomer from the University of Arizona, examined plates he had made on Oct. 11 and 12 of the same area, and he too found the object. The finding was also verified by Caltech research fellow Richard Green, in an examination of plates made on Nov. 3 and 4.

Now that the object has been discovered, the question becomes, "What is it?" There really isn't a definitive answer.

ASTRONOMY interviewed Brian Marsden of the Smithsonian Astrophysical Observatory concerning the object. "We really don't know what it is," he said. It could be an asteroid or a comet or a small planet. We think it may be a lump of cometary material, but for now we really have to call it a minor planet until we can prove observationally that it is or isn't a comet."

The object is rather small (based on size determinations from its brightness) — approximately 100 to 400 miles in diameter (160 to 640 km), or roughly 1/10 the size of the smallest planet, Mercury. Kowal believes the object originated within our solar system as it had an extremely sharp image; comets, which originate outside the solar system, have a fuzzier appearance.

Images of the object have been found on photographic plates dating back to 1895. At that time, and in 1945, the object was at perihelion (the point in its orbit closest to Earth). It should reach perihelion again 19 years from now (1996). In 1920 and 1970 it was at aphelion (the point farthest from Earth). Currently the miniplanet is just past aphelion, or 1-1/2 billion miles from Earth. This means that when the object is closest to us, it's traveling in a path inside the orbit of Saturn; when it is farthest away, it's traveling in a path inside Uranus' orbit.

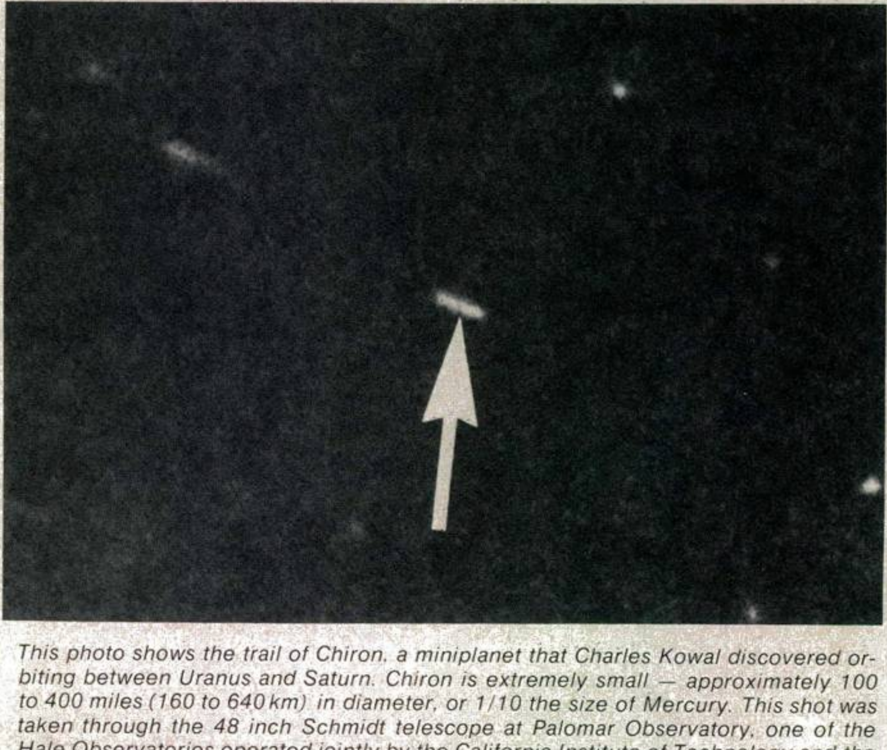
This information was used by Kowal when selecting a name for the object. Kowal chose the name Chiron, after a mythological centaur (half man, half horse). Chiron was known in Greek mythology as the son of Kronos; in Roman mythology Kronos was known as Saturn. Kowal felt the name was appropriate because Chiron's orbit lies between Saturn and Uranus. Chiron was the leader of a group of centaurs, so should more objects be discovered, they can be named after other centaurs.

According to Marsden, "It's curious that the object would be discovered so close to aphelion and that we've never seen it at perihelion when it would be at its brightest. However," he added, "with perihelion occurring in 1945, a lot of observers were otherwise occupied at the time. The Germans, pioneers in observing minor planets, had a program of observing minor planets, but they discontinued it in 1941 and resumed it in 1949."

Chiron could be one of three things — an asteroid, a comet or a small planet.

"Asteroids as we currently define them are rocky objects, and they go out only as far as Jupiter — such as the Trojans in Jupiter's orbit," Marsden said. "Between Jupiter and Saturn it

Miniplanet *continued on page 68*



This photo shows the trail of Chiron, a miniplanet that Charles Kowal discovered orbiting between Uranus and Saturn. Chiron is extremely small — approximately 100 to 400 miles (160 to 640 km) in diameter, or 1/10 the size of Mercury. This shot was taken through the 48 inch Schmidt telescope at Palomar Observatory, one of the Hale Observatories operated jointly by the California Institute of Technology and the Carnegie Institute of Washington. Photograph by Charles Kowal.

Space Program Technology Applied to Meals for Elderly

While three square meals a day are taken for granted by most Americans, getting even one balanced meal each day is a problem for some of the nation's elderly.

Food technology and packaging techniques, developed by NASA's Johnson Space Center (Houston, Tex.) to feed Apollo and Skylab crews during space flight, are being applied in a pilot program to help provide balanced meals to elderly persons who live alone. Physicians, nutritionists and biomedical engineers at the center are working together to design and develop a meal system to supplement the existing National Nutrition Programs for the Elderly.

The effort is part of the agency's Technology Utilization program, in which space developed technology is applied in the solution of Earthbound problems.

Project engineer Gary R. Primeaux reported that surveys have shown that many elderly Americans do not receive adequate nutrition. He cites as contributing factors lack of single serving products, limited mobility, loss of skills needed to prepare balanced meals, limited finances, and often a sense of loneliness or rejection that reduces the incentive to cook and eat nutritious meals alone.

Primeaux says the goal of Meal Systems for the Elderly "is to develop nutritious, shelf-stable, convenient and easily deliverable meals for the elderly".

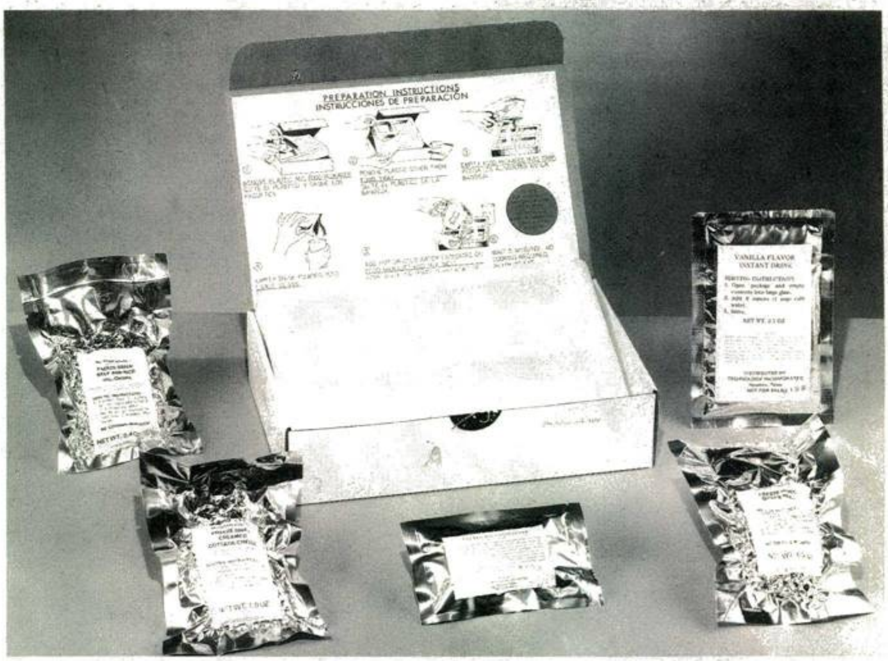
While several programs for home-delivered hot lunches for the elderly are being tried in some cities, there is usually no weekend service and spoilage risk is high. The NASA team developing the meal system is striving to come up with a shelf-stable, multi-meal package that can be distributed by several methods — even parcel post — to senior citizens who live beyond the range of hot meal delivery, or to those in cities where weekend meals are not provided. The team is working toward a meal system that can be opened, cooked, eaten and cleaned up by elderly people living alone.

The basic meal will consist of an entree, two side dishes, dessert and beverage, with a 21 day menu cycle to provide variety from a list of 10 entrees, 20 side dishes, 10 desserts and 5 beverages. Each meal will provide at least 1/3 the daily dietary allowance for elderly persons.

In addition to the Johnson Space Center team developing the meal system technology, the University of Texas Lyndon B. Johnson School of Public Affairs in Austin will assist in demonstrations and distribution of meals. The Texas Research Institute of Mental Sciences in Houston has surveyed attitudes and food preferences, and has run taste tests among potential users.

The program is expected to cost $240,000 of which NASA will fund $125,000; Johnson School of Public Affairs, $90,000; Texas Research Institute of Mental Sciences, $8,000, and United Action for the Elderly, Inc. $17,000. Technology, Inc. and Martin Marietta Corp. are contractors in the development program.

Persons interested in further information should write to Johnson Space Center, referring to this article by code number MSC-16062.



This is a sample meal from the Johnson Space Center's Meal System for the Elderly. Shown clockwise from the right are a vanilla flavored instant drink, freeze dried green peas, chocolate crunch bar, freeze dried creamed cottage cheese, and freeze dried beef and rice with onions. NASA photograph.

US, Europeans Sign Satellite Agreement

NASA and the Netherlands Agency for Aerospace Programs (NIVR) have entered into an agreement on the cooperative Infrared Astronomical Satellite project (IRAS).

The United Kingdom also will participate in the program under a separate agreement between the U.K. Science Research Council and the NIVR.

The Earth orbiting observatory will employ a cyrogenically cooled infrared telescope furnished by the United States, a spacecraft built by the Netherlands, and a spacecraft command, control and data acquisition facility supplied by the U.K. All three nations are participating in the scientific instrumentation and the observing program.

The IRAS mission, involving nearly 500 scientists, engineers and technicians from the three nations, will conduct the first astronomical survey of the entire sky at those infrared wavelengths undetectable by Earth based telescopes (because of the obscuring effects of the atmosphere).

NASA will design and build the infrared telescope, and provide the Delta launch vehicle and launch services; the Netherlands will provide the spacecraft. Integration of the two systems will take place in the Netherlands.

The satellite will be launched into a polar orbit from the U.S. Western Test Range in early 1981. IRAS has a projected one year lifetime to perform the scientific mission.

1st Shuttle Payload to Study Resources and Environment

The first payload to be carried into space by the Space Shuttle will investigate Earth resources, environmental quality and severe storm research in 1979.

The payload, under the management of the NASA Headquarters Office of Applications, will be on the second Orbital Flight Test (OFT-2) scheduled for launch from Kennedy Space Center. Space Shuttle Orbiter 102, sister ship to the "Enterprise" now undergoing approach and landing tests at NASA's Dryden Flight Research Center, Calif., will make the first several space flights.

The orbital flight test program is a series of six developmental missions scheduled for 1979 and 1980, and leading up to operational readiness of the Space Shuttle in May 1980.

The objective of the OFT missions is to evaluate the performance of the Space Shuttle and its systems, and to provide early demonstrations of the Shuttle's capability to do what it is designed to do in space.

The first orbital Shuttle mission (OFT-1) will carry instrumentation to evaluate its performance, and a special package called the Induced Environment Contamination Monitor (IECM) to measure the effects of the Shuttle on the space immediately around it. The IECM will be carried on all six orbital flight test missions.

The payload for the second Shuttle flight, like the Shuttle Orbiter itself, is reusable. This will permit adjustment and modification of the payload instruments and other hardware to allow its use on subsequent flights at relatively low cost.

The first Shuttle payload investigations and the principal investigators currently assigned are:

• *All-Weather Surface Observation Investigation* — Dr. Charles Elachi, Jet Propulsion Laboratory, Pasadena, Calif.

For several years NASA research spacecraft have acquired data about Earth resources using space sensors that see in the visible and near infrared portions of the electromagnetic spectrum. This investigation will extend these observations into the microwave portion of the spectrum.

Using an active microwave system (radar), this project will add a valuable new dimension to the earlier data and also allow observations through cloud cover. The information will be particularly important to mineral exploration and to areas where clouds are present a high percentage of the time. This investigation is also the optimum design for active microwave sensors.

• *Measurement of Air Pollution from Satellites* — Dr. Henry G. Reichle Jr., Langley Research Center, Hampton, Va.

This program will measure the amount and circulation of carbon monoxide in the middle and upper troposphere. This will be the first measurement from space of pollutants in the lower atmospheric levels. As such, this investigation is an important step toward measuring and monitoring global pollution where it most directly affects people and communities on Earth.

• *Shuttle Multispectral Infrared Radiometer* — Dr. Alexander F. H. Goetz, JPL

This project will use a special instrument to provide for testing of various combinations of spectral bands and bandwidths in the near infrared portion of the spectrum. This allows continued research to optimize infrared sensor systems for future Earth resources satellites. On the OFT-2 mission, the instrument will test spectral bands not now used by the Landsat Earth resources satellite, but which appear to have important applications to mineral, oil and gas exploration.

• *Ocean Color Experiment* — Principal Investigator — Mr. Hongsuk H. Kim, Goddard Space Flight Center, Greenbelt, Md.

The bioproductivity of the oceans is an important indicator of the biological health of our planet and the impact of man's activities. It is also of direct interest to commercial fisheries for locating and evaluating fishing areas. This investigation will attempt to get bioproductivity data by measuring variations in water color in the open oceans. These variations are expected to identify concentrations of chlorophyll as an indication of the presence of plankton and algae. Such concentrations are feeding grounds for many commercially sought fish.

• *Nighttime and Daytime Optical Survey of Thunderstorms, Lightning and Convective Behavior* — Dr. Bernard Vonnegut, State University of New York at Albany.

This program will examine the correlation between lightning and various types of severe storms. A standard 16mm movie camera will be used, equipped with a photocell attachment that records lightning flashes as signals on the film's sound track. This is expected to reveal details of convective circulation in storms and their relationship to the character, location and extent of associated lightning discharges. This data will hopefully lead to the development of satellite systems that can identify severe storms day or night.

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Southern Sky Survey Discovers New Local Group of Galaxies Member

A new member of the local group of galaxies has been discovered in the southern constellation Carina. It was identified in early March this year by Dr. Russell Cannon of the Royal Observatory (Edinburgh, Scotland), on plates taken with the United Kingdom's 1.2 meter Schmidt telescope at Siding Spring, Australia.

Cannon described the galaxy as a faint dwarf containing "several thousand" stars. He estimates its distance at a half million light-years, which makes it one of the nearest local group members to us.

Announcement of the Carina dwarf comes as the first installment of the Southern Sky Survey being distributed from the headquarters of the European Southern Observatory in Geneva. The Southern Sky Survey, an extension of the Palomar Sky Survey for the northern hemisphere, is a joint venture between the U.K. and the European Southern Observatory, which operates its own one meter Schmidt camera at La Silla, Chile.

Because of improvements in photographic emulsions and optical design, the sky survey photographs from the U.K. Schmidt reach two magnitudes (six times) fainter than the Palomar sky survey. Galaxy expert George Abell has said that there is "absolutely no question that profoundly important science will very soon emerge" from the study of the Southern Sky Survey plates.

Asteroids Being Studied For Exploration, Mining

Of the thousand or so asteroids looping around the sun and crossing the orbit of Earth, at least several dozen could be excellent targets for exploration, as well as a mother lode for future space miners, according to two Caltech scientists.

Planetary scientist Eleanor Helin and geologist Eugene Shoemaker have reached this conclusion after a four year systematic search for "planet crossing" asteroids — particularly those that cross Earth's orbit, known as "Apollo" objects. Based on their discoveries, as well as other data concerning asteroids, they predict that numerous asteroids will be detected with suitable orbital characteristics for easy rendezvous with spaceships, as well as high enough mineral contents for profitable mining.

Since 1973, when Helin and Shoemaker began their search for near-Earth asteroids, the number of known Earth crossing asteroids has doubled. The Caltech scientists and their colleagues have found 12 new Earth crossers in the past four years — as many as were found in the previous 40 years.

Only recently, however, have the large space rocks — once dubbed "vermin of the sky" — attracted the attention of space colony advocates, who envision projects to transfer the asteroids to Earth orbit or to project chunks of refined asteroidal material to space colony sites to be used in construction. Using asteroidal material would prove far less costly than launching materials from either Earth or the moon, because of the gravity that must be overcome in such launchings.

Among the Caltech scientists' most significant discoveries is 1976AA, the 1,000 meter diameter asteroid which was discovered in January 1976. This was the first asteroid ever discovered which is exclusively Earth crossing; its orbit stays relatively close to Earth's. It was this asteroid that led Helin and Shoemaker to predict that a population of such bodies will likely be found by future searches. (Newly discovered asteroids are designated by the year of discovery, plus a two-letter code which indicates the time of year.)

The scientists' prediction was further supported nine months later, when they independently discovered 1976UA, the second asteroid with this type of orbit. Asteroid 1976UA, a 200 to 300 meter diameter asteroid, has the distinction of being the second closest minor planet known to approach Earth, having passed within 750,000 miles of our planet.

Many of the recently discovered asteroids are unique. For example, asteroid 1977HA, discovered last April by Helin and Caltech student Schelte Bus, could be dubbed the "wrong way" asteroid, for it speeds around the sun in the opposite direction from most other known objects in the solar system.

Shortly after the 1977HA discovery, another Apollo asteroid, 1977HB, was discovered by Caltech astronomer Charles Kowal. Recent orbital calculations reveal this asteroid to be the best candidate for a space mission.

To be a good mission candidate, such an object must have an orbit approximating that of Earth. It must also move in approximately the plane of Earth's orbit, so that a spacecraft would require little fuel to boost itself from Earth to the asteroid.

To be profitably mined, such an object must also be rich in iron/nickel compounds, silicon/aluminum compounds, or other useful materials.

One space colony proponent has contended that a 100 to 200 meter diameter asteroid could provide Earth with enough iron and nickel to last for years. If true, then some of the asteroids discovered in Helin's searches should make her one of the most successful prospectors of all time.

Recognizing the potential of the discoveries, space colony advocates invited Helin to participate in last summer's NASA-sponsored space industrialization study. There she presented her results and made recommendations for an expanded asteroid search program to assure the availability of asteroids with the right orbit and composition for space mining operations. The NASA-sponsored Near Earth Resources Summer Workshop, held last August at the University of California in San Diego, recommended that such asteroid search programs be speeded up.

"Although I was conservative at first about feasibility of some of the space colony advocates' concepts," Helin said, "after working with them I'm convinced that their mining and colonization schemes could be accomplished. I'm also convinced that a stepped-up asteroid search program will increase the discovery rate of qualified candidates to give a basis for realistic planning.

"The results of our search have almost certainly spurred astronomers to greater efforts to report and follow up asteroid trails found on their photo plates," she said. "It's a considerable improvement over past years, when the typical astronomer would ignore asteroid trails

Asteroid *continued on page 70*

Miniplanet *continued from page 65*

seems probable that we would not find orbits that would be stable over the lifetime of the solar system. So it seems rather unlikely that it could be an asteroid in that region. We [Kowal and Marsden] wondered about the possibility of stable orbits between Jupiter and Saturn, and Saturn and Uranus, in thinking of a circular orbit. If we are dealing with circular orbits, Chiron may be a rather large asteroid — perhaps part of an asteroid belt.

"If we are considering an asteroid belt," he continued, "I think we're talking about icy objects. Then the question is, 'Can we really distinguish between an asteroid and rocky cometary material?' "

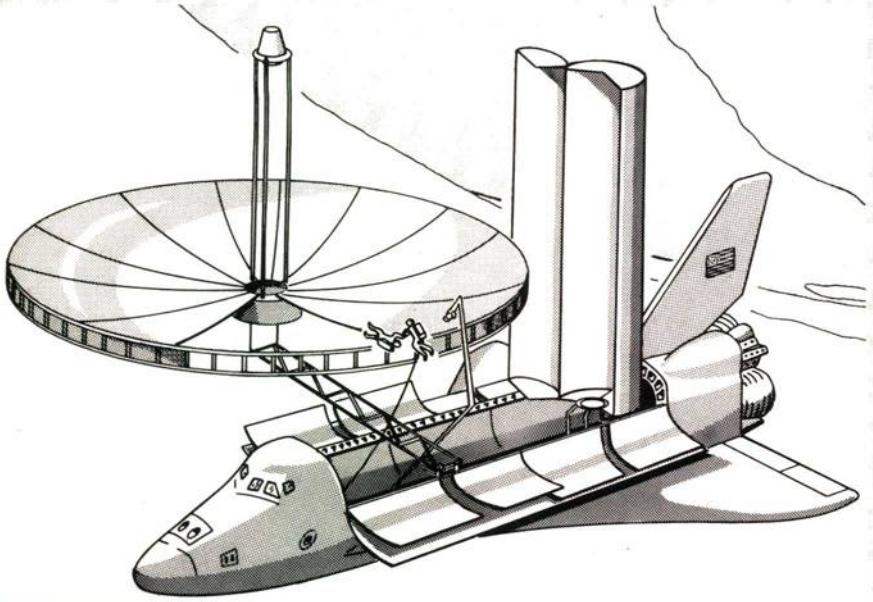
The miniplanet's orbit cannot be exactly stable over the lifetime of the solar system. From the year 1400 to 2550, the average period of Chiron would be 49 years, or 5/3 the period of Saturn. Under such a condition, the planet would have a considerable effect on the object. There were a couple of moderately close approaches to Saturn during that time period — within 102 million miles, and 120 million miles. These didn't seem to upset the object; it continued on its way.

Eccentric or unstable orbits are characteristic of comets, but Chiron doesn't seem to be one, according to Marsden. Water ice would be completely frozen out there, as would ammonia ice or carbon dioxide ice. The only thing that could be volatile would be carbon monoxide or methane. This is perhaps the reason it is such a large lump of cometary material. We've never seen such a large lump, and have never observed anything farther than a billion miles.

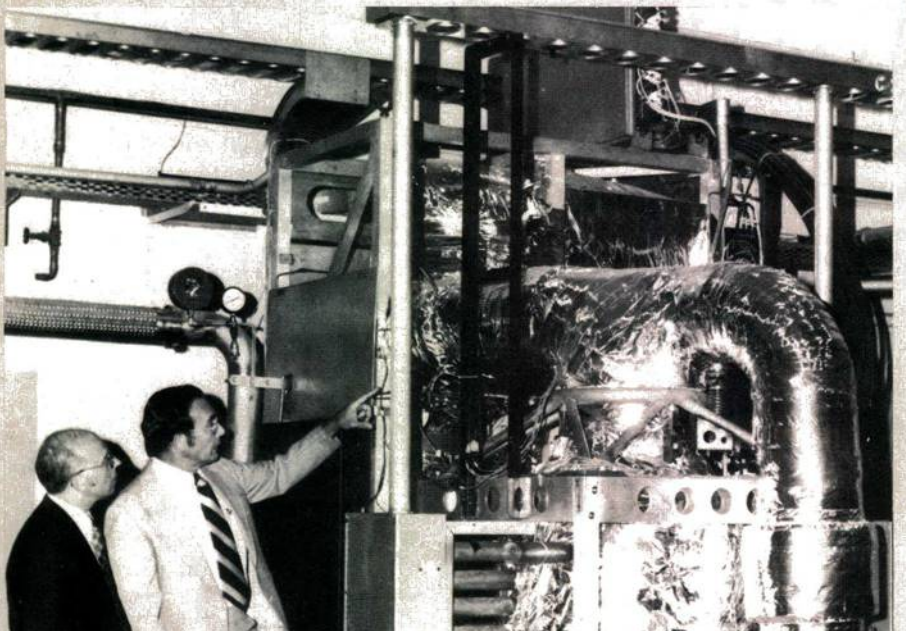
The object's *absolute magnitude* (the brightness of an object seen at one astronomical unit or 93 million miles) is about 5.5, which compares with Phoebe, a moon of Saturn. It's not as big as Neptune's moon Nereid. Phoebe and Nereid may be captured objects; Chiron may be one that wasn't captured.

Generator Proves Successful

A power generator, with potential for use in Earth orbital and deep space missions, has been in operation for 30,000 hours without a break, and is heading for a 50,000 hour goal at NASA's Lewis Research Center.



This illustration features a huge lightweight solar mirror 70 feet (21 meters) across as it is being deployed from the Space Shuttle. The mirror will collect the sun's rays and feed their energy into a Brayton power system, a closed cycle gas turbine system. The Brayton generator will use the sun's energy to supply power for Earth orbiting laboratories and other space oriented operations. NASA artwork.



Lewis Research Center engineers Rudy Spagnuolo (left) and Jack Heller examine the Brayton Power Generator. The generator has been running constantly for 30,000 hours (approximately three years), and is heading toward a goal of 50,000 hours. The generator — a closed cycle gas turbine system — is intended for Earth orbital and deep space missions. NASA photograph.

For more than three years, a Brayton Space Power Generator — a closed cycle gas turbine system — has been running 24 hours a day, 7 days a week.

In its test mode, conventional laboratory electric heaters provide the energy to power the generator. In space, the generator would draw its energy from the sun or from a nuclear source.

"The Brayton engine shatters the myth that only static, nonrotating systems have the endurance potential for long space voyages or exploration," said Jack A. Heller, Lewis engineer in charge of advanced Brayton space power work.

"Our system not only is clearly showing reliability, but it is performing at a high energy efficiency level of 25 percent or better without any signs of degradation," Heller added.

Rigorous space environment conditions of temperature, pressure and speed are being simulated for this prototype, Heller said. For example, the closed gas loop reaches a high temperature of 1,600 degrees Fahrenheit (871 degrees Centigrade) in the turbine, which turns at 36,000 r.p.m. [Automobile engines commonly turn at 3,600 r.p.m. with cylinders cooled to less than 300 degrees Fahrenheit (149 degrees Centigrade.)]

Energy conscious Lewis engineers recycle the test generator's electrical output of 10 kilowatts by feeding some of it back into the laboratory's lighting system.

Testing of the complete Brayton system (named after George B. Brayton, an American engineer) began in 1970 at Lewis' Plum Brook Station near Sandusky, Ohio, in a huge 100 foot (30 meter) diameter vacuum chamber duplicating space environments.

The generator now runs unattended around-the-clock at Lewis' main research complex. Heller believes it could be scaled up to larger sizes with relative simplicity, and could result in even higher efficiencies.

Lewis' closed Brayton power system is similar in principle to an aircraft gas turbine engine. It consists of a rotating unit, a recuperator, a heat source and a waste heat radiator. The rotating unit includes a compressor, turbine and alternator, all mounted on a single high speed shaft supported on gas bearings. The gas bearings support the shaft on a film of gas that is less than the thickness of a human hair.

Lewis is also studying advanced Brayton systems of 60 kilowatts magnitude in support of studies by NASA's Johnson Space Center and Marshall Space Flight Center of an orbiting construction base in space.

Physicist Discovers Galaxy Circled by Stars

Using a newly designed photometer, Dr. Dennis Hegyi has reported detecting matter in the form of a spherical halo surrounding a galaxy 80 million light-years from Earth. He says the matter is composed of billions of previously unseen stars.

According to Hegyi, the halo appears to be massive, possibly containing more matter than what had been thought to be in the spiral galaxy itself. If this is characteristic of other galaxies, he said, the halos might contain enough matter to stop the present expansion of the universe.

Hegyi, an assistant professor of physics at the University of Michigan, said that radio observations of the galaxy had indicated the presence of some unseen matter, but neither the nature nor distribution of the matter could be determined. He designed and built a new light measuring instrument — an annular scanning photometer — which enabled him to detect the presence of the halo or cloud surrounding the galaxy.

The finding, if verified, might help settle a debate among scientists about whether the universe will expand forever, or if the pull of gravity among the galaxies eventually will stop the expansion. This would cause all matter to fall together again into one gigantic primeval nucleus which, according to a widely held theory, existed before a tremendous explosion started the universe on its expansion course.

"A fundamental question," Hegyi said, "is whether there is enough matter in the universe to stop the expansion. It is generally believed that the visible portions of galaxies studied from photographs do not contain enough matter. But it is also generally believed there could be a considerable amount of matter in forms which do not radiate much visible light, and would be difficult to detect."

Hegyi said the halo around the galaxy he observed, NGC-4565 in the constellation Coma Berenices, is so faint that it eluded detection on photographs and other sensitive observing systems. These techniques only reveal the brighter, central disklike spiral of stars well known to astronomers for decades and for which these galaxies have been named.

The annular scanning photometer behaves like a photographic plate although it's capable of detecting light photons photographic emulsions are not sensitive enough to detect. The photometer was used on three optical telescopes from which data was obtained and analyzed (the 36 inch reflector at Kitt Peak National Observatory near Tucson, Ariz., the McGraw-Hill 52 inch reflector at Kitt Peak, and the University of Arizona's 60 inch instrument).

Hegyi, who conducted his research with the help of Garth L. Gerber, a graduate student, reported his finding to the National Science Foundation which supported the research project.

Panel Named to Study In-Flight Explosion

NASA has named a panel to investigate the failure of an Atlas Centaur launch vehicle on Sept. 29, which resulted in destruction of the rocket and an Intelsat IV-A communications satellite 55 seconds into the flight.

The explosion occurred during the Atlas first stage firing when the Comsat Intelsat satellite was about five miles (eight kilometers) downrange over the Atlantic Ocean. It had been launched from Kennedy Space Center.

Asteroid

continued from page 68

found on their plates, or even discard the plates if the trail spoiled a plate made for a specific purpose."

Asteroids are detected by setting the telescope to follow the movement of the star field and then photographing that field for an exposure time of 10 to 20 minutes. The star field shows up on the plate as a pattern of dots, while the asteroid, moving with relatively greater speed and nearer Earth, will show up as a long streak.

So that the asteroid will not be lost to future astronomers, it must then be found and photographed on subsequent nights so that its orbit can be computed. Other astronomers have found it possible to deduce the compositions of asteroids by measuring the light reflected from them. Helin, aided by Caltech students, has conducted her search with the 18 inch (46cm) Schmidt telescope at Palomar Observatory.

According to Helin, the asteroid search program, funded by NASA's Planetary Geology Program, was not begun with futuristic plans for mining or colonization, but to estimate the populations, size distributions, and collisional lifetimes of the Earth-crossing objects. Such information would allow a better understanding of the history of Earth and neighboring planets.

"Craters on Earth, the moon and other terrestrial planets were produced mainly by impacts with these objects," said Helin.

"If we can learn more about such asteroids, we will gain greater insight into the impact and cratering rate occurring on the terrestrial planets in the past. This will tell us about the evolution of our solar system."

Many scientists believe the asteroids were formed by accretion of material during formation of the solar system, but that these bodies did not accumulate enough material to become full-fledged planets. If this is so, these small "planetesimals" almost certainly represent samples of unaltered primordial material — the building blocks of the early solar system, Helin said.

The Caltech scientists are also interested in the asteroid search because Earth could possibly be struck by one of the objects in the future. However, they point out, the possibility of such a collision is extremely small, even over a period of many centuries.

"Many believe that the megaton sized explosion that devastated a remote area in Siberia in 1908 was a comet entering the atmosphere," Helin said. "Several of our discoveries have been objects which pass relatively close to Earth, in terms of astronomical distances. As we detect more and more near-Earth objects, we can calculate more precise estimates of asteroid populations, and predict more reliably how often our planet might suffer an impact from one of these near-Earth bodies."

Helin recalled a tense period of a few hours' duration several years ago when preliminary calculations on an object the scientists had discovered suggested that its orbit placed it on a collision course with Earth. However, further calculations indicated that the object was actually orbiting Earth, not the sun, and was therefore probably the remains of a rocket launch — perhaps a discarded fuel tank. But such an episode demonstrates that if such a large cosmic object were discovered to be on a collision course with Earth, there would not be any means of averting such a catastrophe.

Although asteroid 1977HB is currently the best candidate for rendezvous and exploration (and perhaps mining), many more such bodies with similar or better orbits must be found before a convincing conclusion about the economics of space mining can be made, Helin said. To find these objects, Helin and Shoemaker are seeking an expanded search program that would include larger telescopes and greater coordination with other astronomers throughout the world.

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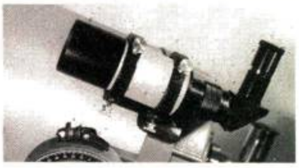

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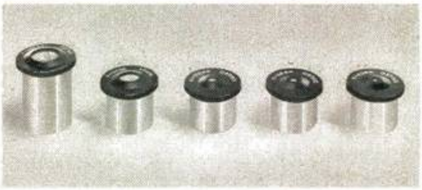

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Toronto, Ontario
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Ontario, Canada K2P 2C4

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Canada M5V 1Z1

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Canada R3E 2S8

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& Nature
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Winnipeg, Manitoba
Canada R3B 0N2

Museum Planetarium Shop
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Vancouver, B.C.
Canada V6J 3J9

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NEW DEALER INQUIRIES INVITED

11/10/77

STAR DOME

FEBRUARY

by

John G. Harmon and James Mullaney

"By Jiminy!" How many people have said these words without realising that they were taking an ancient Roman oath "By Gemini" or "By the Twins"? The twins were considered the guardians of Rome and appeared on Roman coins pictured as two horsemen.

The constellation Gemini was thought to be especially propitious by Greek and Roman mariners, who considered the twins "a welcome couple to a vexed barge". Because of this, the twins were often symbolized by two stars over a ship. The poet Homer wrote:

> "When wintry tempests o'er
> the savage sea
> Are raging, and the sailors
> tremblingly
> Call on the Twins of Jove
> with prayer and vow
> Gathered in fear upon the
> lofty prow...."

This relationship with the sea stems perhaps from the twins being among the group of Argonauts who accompanied Jason on the voyage to Colchis. During a violent storm, Saint Elmo's (Saint Helen's) lights appeared over each of the twin's heads. With the appearance of this electrical phenomena, the storm abated. Ever since, mariners have felt that the appearance of a double light of the "Fire of Saint Helen" was a favorable sign. This ability of the twins to calm a storm was strongly believed in ancient times.

These nights, Gemini is very nearly overhead as it straddles the portion of the ecliptic where we find the sun during the warm days of summer. This star pattern consists of two roughly parallel lines of stars, with the "twin" stars Castor and Pollux side by side at the top. The separation of about 4-1/2 degrees between Castor and Pollux was used by the Arabs as a unit of measure which they called the "Ell". Although Pollux is now about 1-1/2 magnitudes brighter than Castor, it bears the Greek letter Beta, which is usually assigned to the second brightest star in the group. Apparently this was not always so. It's generally believed that until about 300 years ago, Castor was the brighter of the pair.

The constellation has almost always represented some concept of duality. To the Persians, it was "Du Paiker" or two figures. In Arabia, it represented two peacocks. Egyptians thought that it was their gods Horus the elder and Horus the younger. The Yin Yang, or the two principles, were seen there by the Chinese, and Eskimos thought they were two door stones of an igloo.

In the Alfonsine Tables, written by Moorish astronomers in 1252 A.D., the constellation was depicted as Adam and Eve. These tables take their name from King Alfonso of Castile, and are strongly Arabic in nature. They were the first important catalog of stars after the time of Ptolemy, and were used until the 16th century.

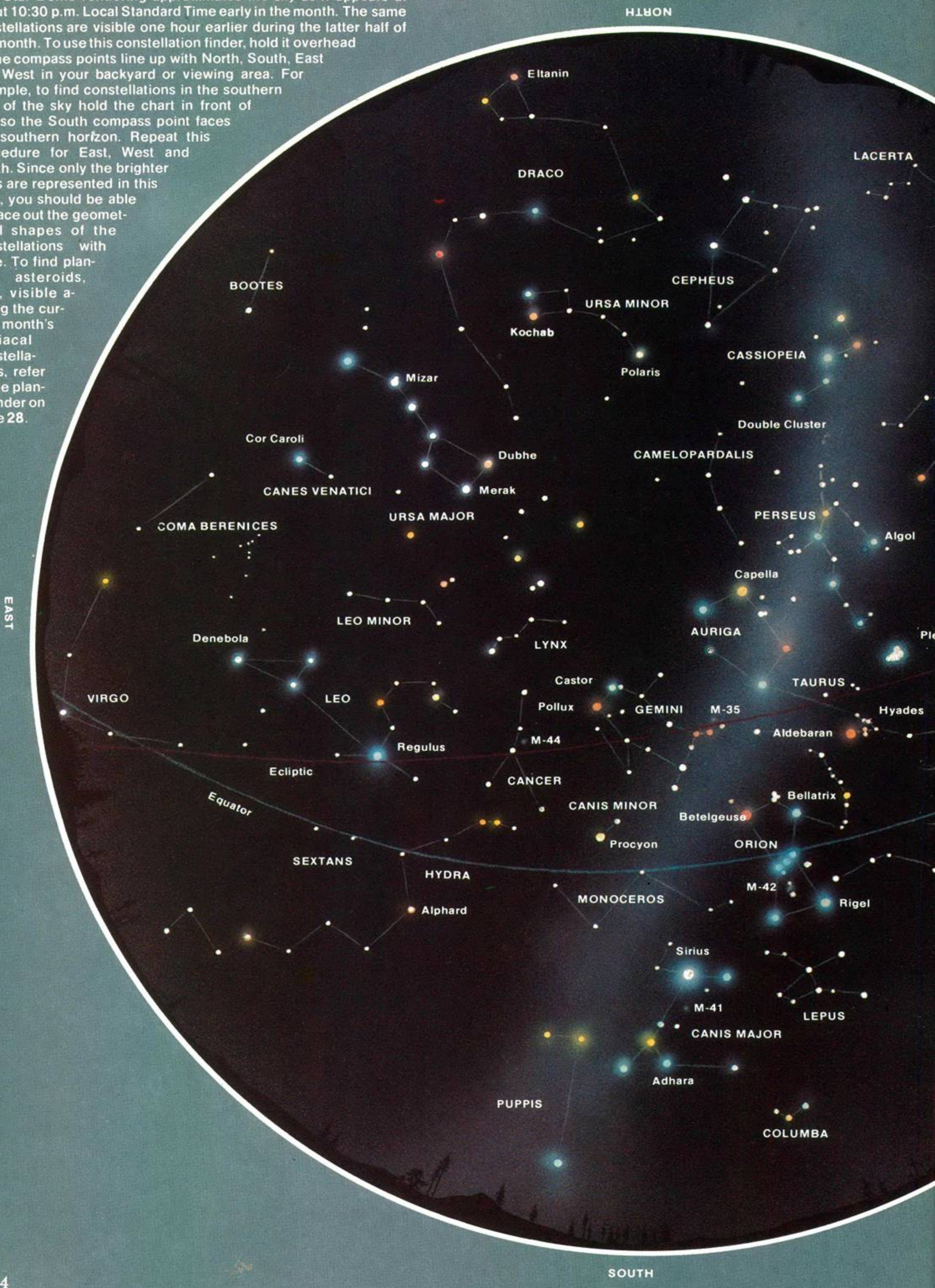
Our name for the constellation, Gemini, comes from the Greek myth of the Dioscuri, the twin brothers Castor and Pollux. Castor was said to be a great horseman while Pollux was a noted boxer. Their mother was Leda, wife of Tyndareus, king of Sparta. While the king was acknowledged as being Castor's father, Pollux was said to be the son of the god Zeus who, according to legend, came to Leda in the form of a swan. The ancient belief was that the twins had two different fathers — one of them supernatural! Out of this unusual union came two other children as well: Clytemnestra, and the famous Helen of Troy.

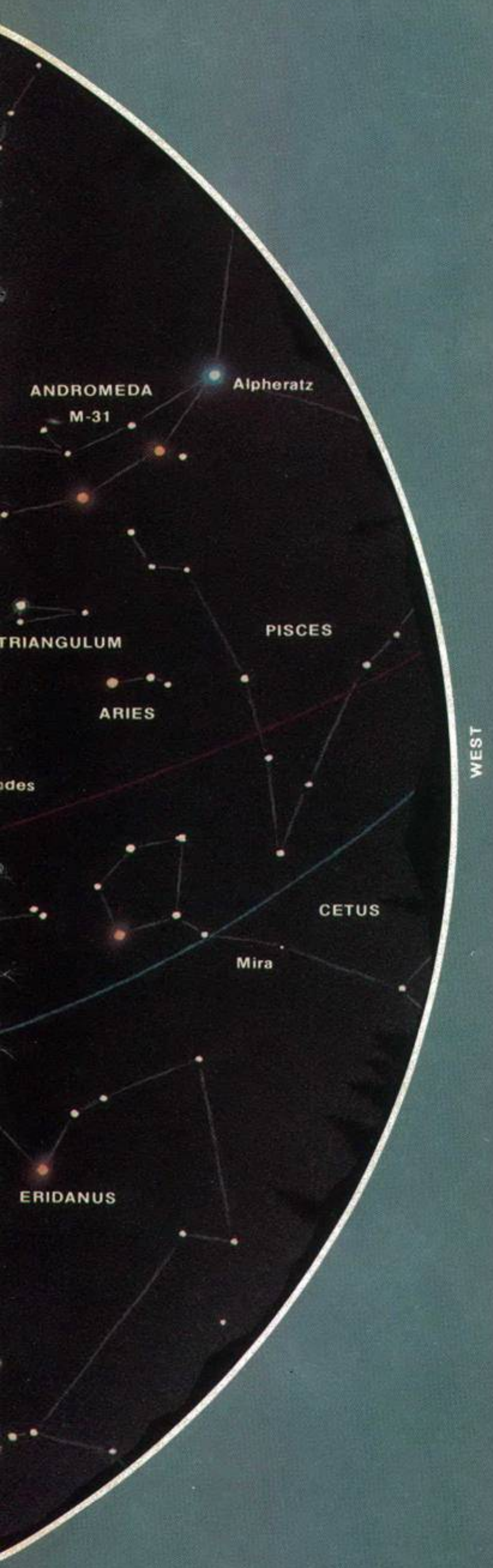
Needless to say, this illustrious family figured prominently in Greek legends. On the aforementioned voyage of the Argonauts, Pollux's boxing skill played an important part. On their way to Colchis to obtain the Golden Fleece, the Argonauts stopped in the land of the Bebrycians. The only way that they could obtain water from a local spring was for one of the Argonauts to accept the challenge of King Amycus to a boxing match. Pollux was the logical choice, and he killed the Bebrycian king with one blow.

Of the various stories about the twins, the one that concerns their placement in the sky is about the death of Castor. The Dioscuri (Castor and Pollux) had carried off their cousins, Phoebe and Hilaria, who were about to be married to yet another pair of cousins, Idas and Lynceus. The pair promptly gave chase, and caught up with the abductors.

In the ensuing battle, Pollux killed Lynceus, Castor was mortally wounded by Idas, and Idas in turn was struck down by a thunderbolt from Zeus. Pollux, being the son of Zeus, was immortal. He begged his father to allow him to share his immortallity with his dying brother, Castor. This request was granted, and the brothers are now always together spending their days alternately in heaven and

This Star Dome rendering approximates the sky as it appears at about 10:30 p.m. Local Standard Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page **28**.


NORTH
Eltanin
LACERTA
DRACO
CEPHEUS
BOOTES
URSA MINOR
Kochab
CASSIOPEIA
Polaris
Mizar
Double Cluster
Cor Caroli
Dubhe
CAMELOPARDALIS
CANES VENATICI
Merak
PERSEUS
URSA MAJOR
COMA BERENICES
Algol
Capella
EAST
LEO MINOR
AURIGA
Ple
Denebola
LYNX
Castor
TAURUS
VIRGO
LEO
Pollux
GEMINI
M-35
Hyades
M-44
Aldebaran
Regulus
Ecliptic
CANCER
Equator
Bellatrix
CANIS MINOR
Betelgeuse
Procyon
ORION
SEXTANS
HYDRA
M-42
MONOCEROS
Rigel
Alphard
Sirius
M-41
LEPUS
CANIS MAJOR
Adhara
PUPPIS
COLUMBA
SOUTH



in the underworld, symbolized by the rising and setting of their constellation.

Aside from the mythological aspects, Gemini has another claim to fame. On March 13, 1781, Herschel discovered the planet Uranus near the star Eta, or Propus, which marks Castor's left foot. Perhaps "discovered" is not exactly the right word, as the planet had previously been observed as a star by other observers at least 22 times! Herschel at first thought it was a comet. Later, after realizing the true nature of his discovery, he named it Georgium Sidus or "George's Star", after England's King George III. Other European astronomers preferred to call the new planet "Herschel". The name Uranus was suggested by Bode to retain the mythological nature of the planets. Bode thought that the name of the oldest of the gods was ideally suited to the most distant of the then known planets.

An even older connection between Gemini and planetary observations dates back to 4 B.C. The planet involved interestingly enough was Jupiter (the Roman name for Zeus), which passed twice in front of one of Gemini's stars during that year. These occultations were observed by Aristotle and were the earliest such observations to be recorded.

It is also with respect to this part of the sky that we find perhaps the oldest astronomical record of all, dating back some 6,000 years. On Babylonian monuments and boundary stones, we find the symbol called the "Triad of Stars". This symbol consisted of a crescent lying on its side with two stars beside it. The "Triad" is actually a picture of what you would have seen in the evening twilight sky of about 4,000 B.C. on the first day of the new year. It shows us the first new moon of the year appearing as a thin crescent near the stars Castor and Pollux. Because of precession and changes in the calendar which have occurred over the past 60 centuries, this is no longer the case. The new years back then began near the first day of spring, and it was perhaps the equal length of day and night during that time of year that first suggested the concept of "twinness" that we see symbolized by the constellation even today.

Close-Up

Gemini Region

The zodiacal constellation Gemini is a neat, "self-contained" figure that has the form of an elongated parallelogram, crowned by the twin luminaries Castor and Pollux. All of the classic observers were enthusiastic about this region of the sky: Olcott regarded it as "a rich field for the telescopist" and Barns, "a dazzling exploration field for the gem-hunter...an embarrassment of riches in every quarter".

Among the sights for binocular and RFT users here is the open cluster M-35 (a stunning "jewel box" described in detail below), and the region about the star Gamma (γ) Geminorum. Olcott pointed out that the latter has "a remarkable array of stars near it", and Barns saw it "framed in jewels". Webb noted that "with low power, minute stars radiate from it every way; pretty field."

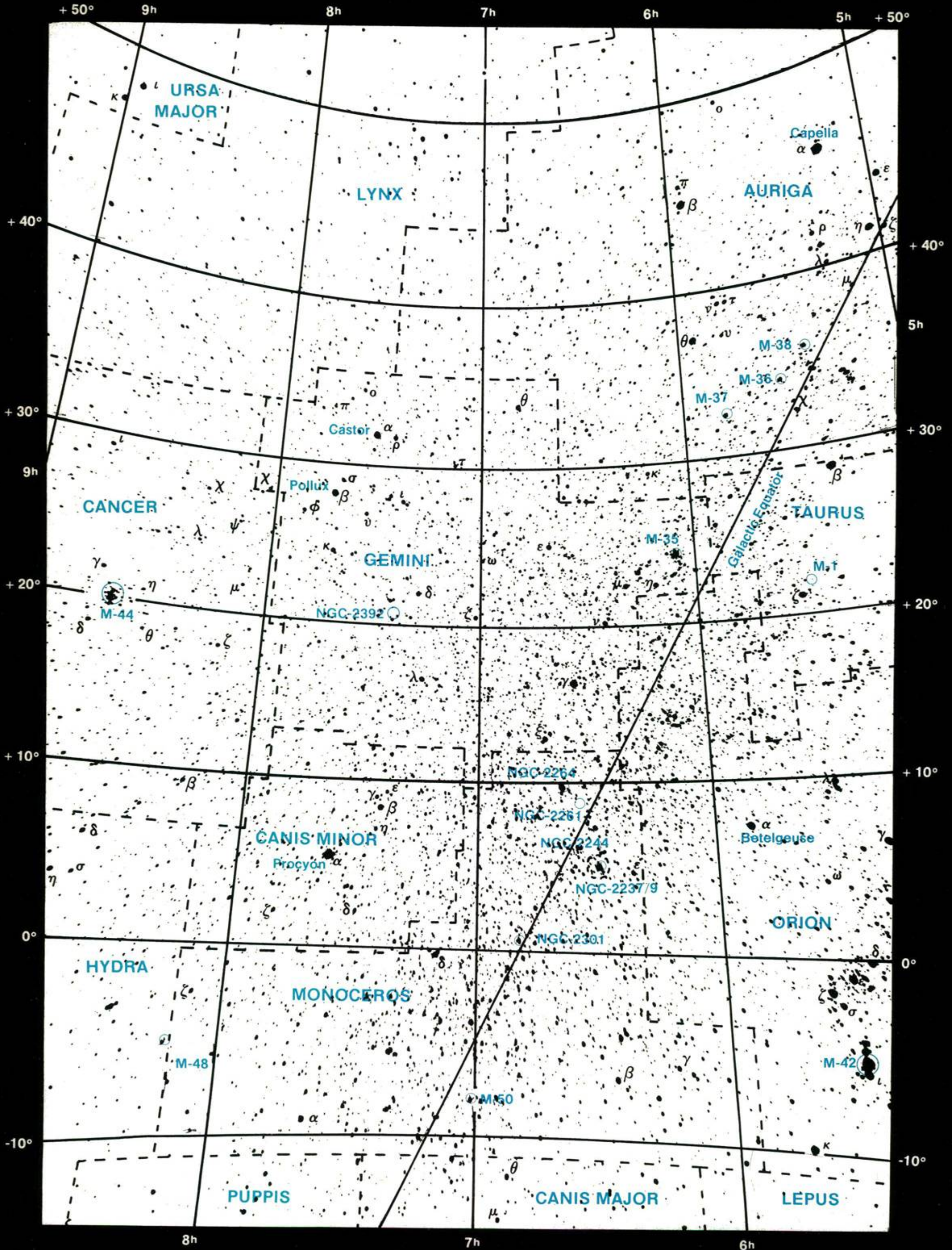
Another object of note is the red, semiregular, variable double star Eta (η) Geminorum, where Webb found "glorious sweeping". It was near this object that Sir William Herschel discovered the planet Uranus on March 13, 1781, while sweeping with a homemade metal mirrored reflector of 6.2 inches aperture at 227 power. This ranks as one of the greatest finds ever made by an "amateur" astronomer (as Herschel considered himself).

Castor [Alpha (α) Geminorum]

Foremost of the hoard of double stars in this month's region is the splendid visual binary, Castor. Telescopically, this object is a triple system, consisting of two blazing white suns of magnitudes 2.0 and 2.9, presently a tight two seconds of arc apart. There is also a reddish-orange third star found 73 seconds distant, which is known variously as Castor C or YY Geminorum. It is a rapid eclipsing binary with a period of just 19.5 hours. Normally a 9.1 magnitude object, it fades noticeably during eclipse to a minimum of 9.6 — a full half magnitude!

The duplicity of Castor was discovered in 1718 by English astronomers Bradley and Pound. The certainty of its orbital motion first fully convinced William Herschel of the existence of binary systems (another of his many discoveries at the eyepiece), and his son John considered it the brightest and finest of all double stars visible from the northern hemisphere.

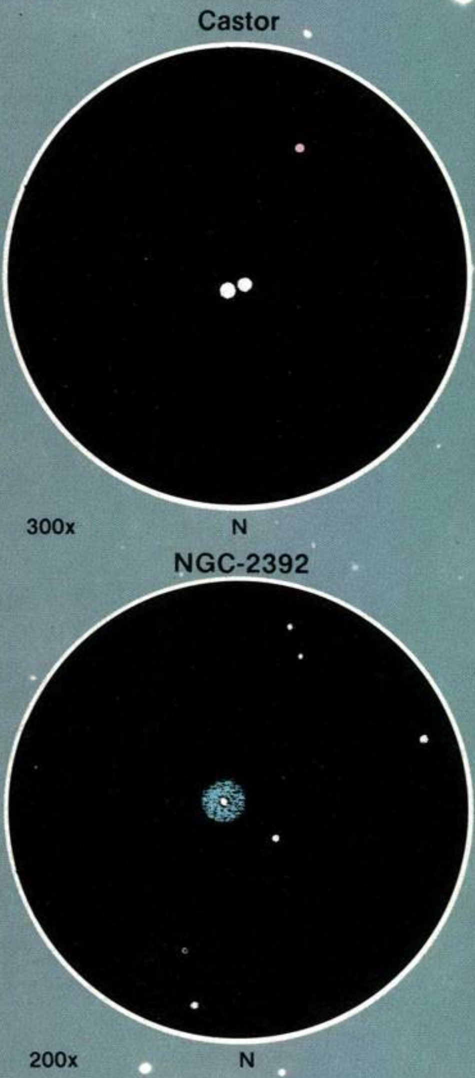
The A-B pair revolves in a (somewhat uncertain) period of about 420 years, while Castor C requires an estimated 100 centuries to make a circuit about them! From a maximum separation of more than six seconds in the late 1800s, the bright duo was closing until 1969, at which time it reached a minimum near 1.8 seconds — just beyond the reach of a two inch telescope. It is now slowly opening toward another maximum expected about the year 2100. Because of orbital geometry, Castor actually dis-


+50°
9h
8h
7h
6h
5h
+50°
URSA MAJOR
LYNX
AURIGA
Capella
+40°
+40°
5h
M-38
M-36
M-37
+30°
+30°
Castor
9h
Pollux
CANCER
GEMINI
TAURUS
M-35
Galactic Equator
M-1
+20°
+20°
M-44
NGC-2392
+10°
+10°
NGC-2264
NGC-2261
CANIS MINOR
Procyon
NGC-2244
Betelgeuse
NGC-2237/9
ORION
0°
NGC-2301
0°
HYDRA
MONOCEROS
M-48
M-42
M-50
-10°
-10°
PUPPIS
CANIS MAJOR
LEPUS
8h
7h
6h

Photograph by Brad Wallis and Robert Provin
Map by Richard Berry

plays two *apparent* maxima and minima of angular separation during each orbital revolution.

Castor B was south of the primary in 1954 and will be due east of it in 1982; presently it lies near position angle 104 degrees. The changes in both position angle and separation of the A-B pair have been noticeable in small telescopes over the past few decades — a vivid display before our eyes of binary motion in the depths of interstellar space! The C component appears fixed near position angle 165 degrees (slightly east of south in the sky).



Top: Castor is one of the brightest double stars in the sky. Its two most luminous components are currently separated by a mere two seconds of arc, while a third (reddish) member of the system rotates much farther away. We see Castor here through a six inch reflector at 300 power. Bottom: NGC-2392 is a not-easily-forgotten vivid planetary nebula. Sometimes called the Clown Face or Eskimo nebula, it consists of a bright blue haze surrounding a central star. Our drawing shows it as seen through an eight inch reflector at 200 power. Drawings by James Mullaney.

The close pair will become easier to split with each passing year; all three stars can presently be seen nicely with a three inch refractor at 100 power on a steady night. Larger apertures provide a superb view, as suggested in our drawing with a six inch reflector at 300 power.

Castor C is of spectral class M10, and has an unmistakable orange or ruddy cast to it. The colors of the bright duo, however, are much more subtle and difficult to pin down. Both are early A-type suns; this class is usually regarded as either blue-white or green-white in hue. Both stars appear bright white on first glance, but closer inspection will reveal the presence of definite off-white tints.

Pickering included Castor in his roster under finest white double stars. Olcott saw the bright pair as both greenish-white and called it a "beautiful object". Bernhard, Bennett and Rice also listed both as greenish-white, with the comment "very luminous pair; one of the finest doubles". Smyth noted the tints as "bright white, pale white"; Brown saw both as blue-white, and Muirden both yellowish. The most unusual impression is that given by Barns: "Beautiful orange-blue pair for small glass." And finally, Webb considered Castor an "excellent object for small telescopes", and called the faint star reddish or purple in hue. We should remember that most of these comments were made at a time when Castor was a much wider pair than at present.

Not only does Castor C have a close companion as mentioned above, but so too do A and B! Both objects are spectroscopic binaries having periods of about nine and three days, respectively. Thus what looks to be a single bright star to the unaided eye is in reality a complex multiple system consisting of at least *six* suns — all in motion about each other, serenely sailing the ocean of night as a close-knit family! Only our vantage point from a distance of 45 light-years keeps us from seeing the Castor system in its full glory.

Pollux [Beta (β) Geminorum]

Deserving of our attention as a member of the very exclusive "first magnitude club", Pollux ranks as Gemini's brightest star despite its Greek letter designation of Beta. At magnitude 1.2, it actually shines about a half magnitude brighter than nearby Castor, which carries the first place label of Alpha.

Olcott repeated a popular misconception when he pointed out, "A few centuries ago, Castor was brighter than Pollux, which now exceeds it in brilliance." Actually, Pollux has almost certainly always been the brighter of the two during recorded history (see Star Dome, January 1977, for details). He noted it in his classic work as a multiple star, having at least six very faint components. Webb recorded the brightest of these as being only 10th and 12th magnitude; probably they are merely faint field stars. This lovely gem is a yellowish-orange giant sun of spectral type K0, lying just 35 light-years from us.

Perhaps a word of warning is in order before moving on: More than one novice stargazer has mistaken Pollux for Castor, and attempted with great frustration to resolve what should be a showpiece double where there is only a solitary sun!

NGC-2392

Our next stop is a visit to a vivid blue planetary nebula with a bright central star. This is NGC-2392, situated just two degrees southeast of the double star Delta (δ) Geminorum.

Selected Objects — Gemini Region

Object	Type	Mag.	Size/Sep.	R.A. (1950)	Dec.
* NGC-2158	GC	12	4'	06^h04^m	+24°06'
* M-35	OC	5.3	40'	06^h06^m	+24°20'
η (Eta)	★2,V:233d	3.1-3.9,8.8	1.3"	06^h12^m	+22°31'
20 Geminorum	★2	6.7,6.9	20"	06^h29^m	+17°49'
38 Geminorum	★2	4.7,7.6	7"	06^h52^m	+13°15'
δ (Delta)	★2	3.5,8.1	6"	07^h17^m	+22°05'
* NGC-2392	PN	8.3	47"x43"	07^h26^m	+21°01'
*α (Alpha)	★3	2.0,2.9,9.1	2",73"	07^h31^m	+32°00'
*β (Beta)	★1M	1.2	—	07^h42^m	+28°09'

* Detailed in Close-Up

★2 = Double Star
★3 = Triple Star
★1M = First Magnitude Star
V:#^{d} = Variable Star, Period
PN = Planetary Nebula
OC = Open Cluster
GC = Globular Cluster
Mag. = Magnitude
Sep. = Separation

Sweep for it with a low to medium power eyepiece — you'll find it right next to an eighth magnitude star. It's a surprising sight even in a three or four inch telescope.

This object is also designated H-IV[45], indicating that it was the 45th discovery in William Herschel's class IV (planetary nebulae). It measures a nearly circular 47 by 43 seconds in size, and shines with the light of an out-of-focus eighth magnitude star. Its stellar nucleus is listed as 10.5 photographic magnitude in most catalogs.

Visually, NGC-2392 looks smaller and the central star much brighter than the above figures suggest. Brown gave values of 40 seconds and eighth magnitude, while Norton made them 25 seconds and 9.5 magnitude. The NGC itself lists the nucleus as ninth magnitude. Bernhard, Bennett and Rice left this description: “Called curious and remarkable; a star of magnitude eight or nine enveloped in a bright nebulosity.”

NGC-2392 has two nicknames: the Clown Face, or the Eskimo nebula. Dark structures in its disk that can be glimpsed in larger instruments at high magnifications are even more striking on observatory photos of this object, causing it to look very much like its namesakes.

Barns' description of this planetary was: “Nebular unit...worth many returns. A gem-field!” In six inch and larger telescopes the view is exceptional — a bright bluish haze surrounding a sharp central sun, as shown in our sketch with an eight inch reflector at 200 power.

The most detailed and fascinating account of NGC-2392 is that given by Webb, which we quote in full: “William Herschel observed this object as a ninth magnitude star, ‘with a pretty bright nebulosity, equally dispersed all around: a very remarkable phenomenon.’ John Herschel described it as an eighth magnitude star, ‘exactly in the center...of an exactly round bright atmosphere 25 seconds in diameter.’ Smyth, who rates it 7.5 magnitude, says he ‘could only bring it to bear as a burred star.’ I was so much surprised at the result in my inferior telescope, that I cannot help supposing some temporary impediment to distinct vision at Bedford [Smyth's site], for on coming accidentally across it in 1850 I found such a conspicuous nebulosity that I thought it was either damp on the eye-lens, or a telescopic comet; and in 1852 I entered it as ‘a bluish nebulosity quite like a telescopic comet.’ [In] 1856, with 5-1/2 inch [refractor] I perceived a very faint trace of a brighter border south a little following. The Earl of Rosse saw a marvelous object: a star surrounded by a small circular nebula, in which, close to the star, is a little dark spot; this nebula is encompassed, first by a dark, then by a luminous ring, very bright, and always flickering; perhaps a spiral. Buffham sees the dark ring with nine inch [reflector]; Key's 18 inch mirror showed two concentric bright rings and the dark spot.”

Surely this narrative will motivate you to go to the eyepiece and see for yourself that such wondrous things as these are hidden in the night sky! This tiny stellar crypt awaits your inspection across a gulf of more than 10,000 light-years; don't disappoint it, and it won't disappoint you!

M-35 and NGC-2158

Our final offering this month combines a showpiece open cluster with a ghostly companion whose exact nature is somewhat of a mystery. The former, M-35, is visible as a faint patch to the unaided eye on a dark night — and it's a superb sight with even the slightest optical aid. The latter is NGC-2158, a small dim cloud lying near the southwestern edge of M-35 itself. This strangely dissimilar duo can be found about two degrees northwest of the variable/double star Eta Geminorum.

M-35's vital statistics are an integrated magnitude of 5.3 and an angular diameter of 40 minutes. This clan boasts at least 120 member stars, and is considered intermediate-rich in concentration as open clusters go. It is large and uniform, and needs at least a one degree eyepiece to be fully appreciated. Even at 45 power on a three or four inch scope, it's obviously one of the finest objects of its kind in the heavens.

Pickering made room for it in his list under the category of finest irregular clusters, remarking that its “stars are arranged in part in curved lines.” Bernhard, Bennett and Rice rated M-35 as superior to the double cluster in Perseus, and noted: “Faint stars form curves and festoons, with a reddish star in the center.” Norton's description was “fine open cluster of bright stars in streams, with many fainter ones”, while Barns simply stated “strikingly beautiful”!

Olcott called attention to the field about M-35 which contains “two wonderful streams of little stars” that “run parallel northwest on each side of the cluster”; he considered this glittering stellar commune to be one of the finest in the heavens. Messier observer Holyoke called it “One of the most strikingly beautiful galactic clusters. Stars seem to stream out from the center....There are few better objects in the sky for star parties and impressing beginners.”

It was Webb, however, who again gave the most complete account of this object: “Beautiful and extensive region of small stars, a nebula to the naked eye: how differently Lassell's 24 inch mirror shows it, his own words will best tell: ‘A marvelously striking object. No one can see it for the first time without an exclamation of wonder and delight; the field of view, 19 minutes in diameter...is perfectly full of brilliant stars, unusually equal in magnitude and distribution over the whole area. Nothing but a sight of the object itself can convey an adequate idea of its exquisite beauty.’ Smyth observes that the stars form curves, often commencing with a larger one. Elegant festoon near center, starting with a reddish star; nine inch speculum.”

This description was compiled in 1871. In 1882, Webb noted “no ruddy star” was visible, and other observers after him recorded it as only pale yellow. How do you see this star, nearly a century later?

With all the attention given M-35 itself, it's little wonder that its misty companion NGC-2158 is overlooked or forgotten by most deep sky observers. Herschel first noted it, entering it in his catalog as number 17 in his class VI (very compressed and rich clusters of stars). Webb called attention to it under his description of M-35: “About 1/2 degree south preceding, just beyond a group of outliers, is H-VI[17], a faint dim cloud of very minute stars.”

NGC-2158 is officially listed as an open cluster just four minutes of arc in size and about 12th magnitude. Although quite faint, it can be glimpsed on a dark night with averted vision even in a 2.4 inch refractor at 35 power. Both to the eye at the telescope and on photographs (especially the Palomar Schmidt plates), this object looks more like a globular than an open cluster. In fact, the revised New General Catalogue now lists it as the former! Perhaps — like M-11 in Scutum and other objects we've encountered here in the past — it is intermediate between the two types, or “semiglobular” in makeup?

Even the distance of NGC-2158 is somewhere between that of remote open clusters and the closest globulars. Its apparent proximity to M-35 is merely coincidental, for we view it from a depth of some 15,000 light-years — five times the distance of its spectacular and much-vaunted Messier companion.

Seeing with your own eyes celestial glories like those of the Gemini region makes it easy to understand sentiments like that recently penned by University of California astronomer Ivan King: “The astronomical universe is a beauty to behold, a wonder to contemplate, and a challenge to understand.”

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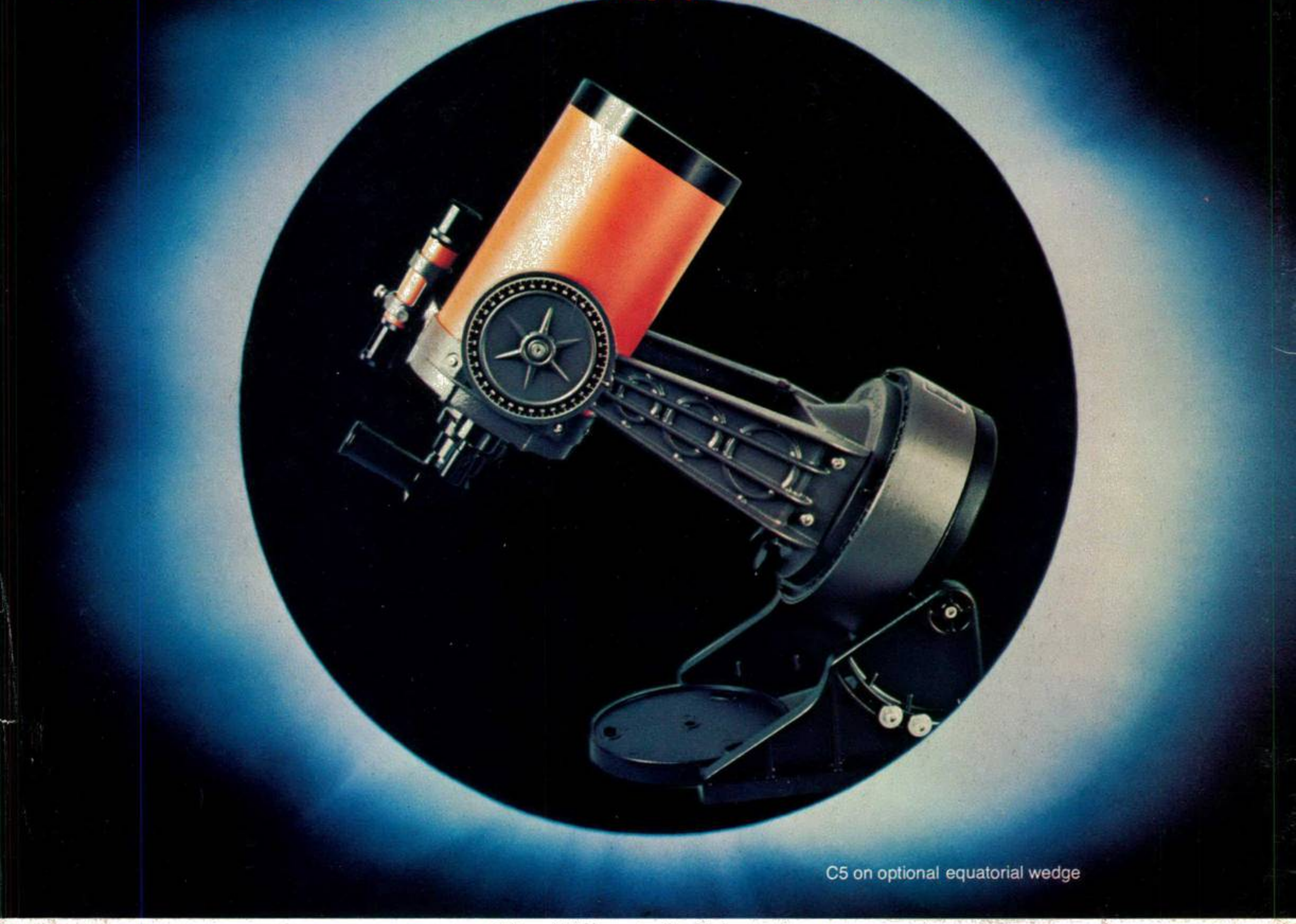

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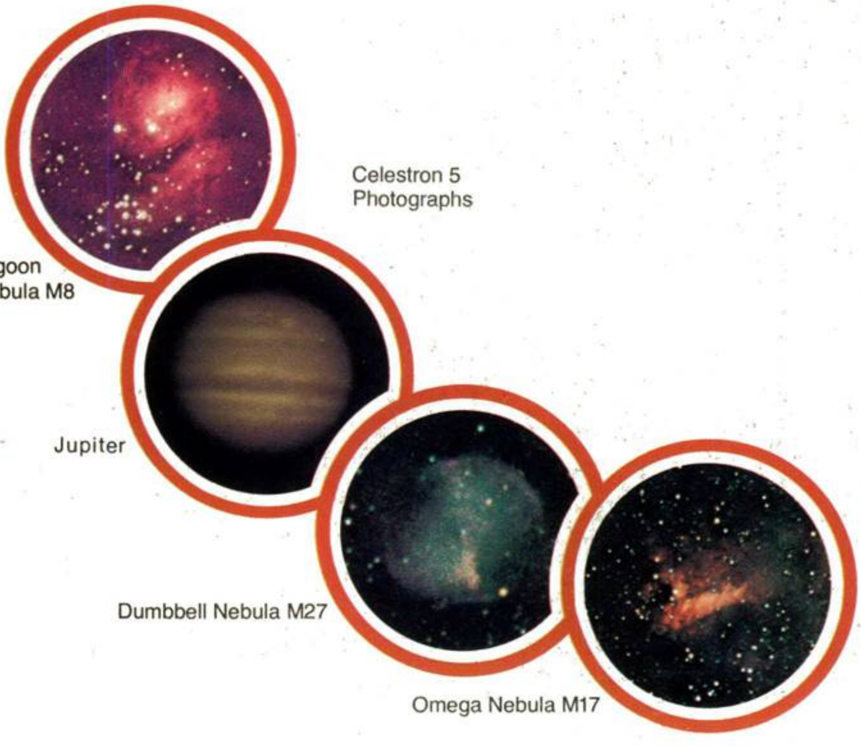

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